EFFECT OF PHOSPHATE AND ZINC SOLUBILIZING MICROBES ON PROFITABILTY AND PRODUCTIVITY OF FIELDPEA

M. Sc. (Ag.) THESIS

by

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COLLEGE OF AGRICULTURE
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EFFECT OF PHOSPHATE AND ZINC SOLUBILIZING MICROBES ON PROFITABILTY AND PRODUCTIVITY OF FIELDPEA

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

SWEETY ANANT

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CERTIFICATE - I

This is to certify that the thesis entitled **"Effect of phosphate and zinc solubilizing microbes on profitability and productivity of fieldpea"** submitted in partial fulfillment of the requirements for the degree of **"Master of Science in Agriculture"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Sweety Anant** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged.

Date: **Chairman**

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member	:	**Dr. R. R. Saxena**	....
Member	:	**Dr. Nitish Tiwari**	....

CERTIFICATE - II

This is to certify that the thesis entitled **"Effect of phosphate and zinc solubilizing microbes on profitability and productivity of fieldpea"** submitted by **Sweety Anant** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the Department of Agronomy has been approved by the external examiner and Student's Advisory Committee after oral examination, under the chairmanship of Head of the Department.

Date **Signature of Head**

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Approved/ Not approved ________________

Director of Instructions ________________

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LIST OF ABBREVATIONS

Abbrevation	Full form	Abbrevation	Full form
%	Per cent	@	At the rate of
°C	Degree Celsius	CD	Critical Difference
d.f	Degree of freedom	CGR	Crop growth rate
RGR	Relative growth rate	LAI	Leaf area index
DAS	Date of sowing	*et.al*	And his co-worker
HI	Harvest Index	LAD	Leaf area duration
Ha^{-1}	Per hectare	cm	Centimeter
Fig	Figure	*viz*	For example
m^{-2}	Meter per square	No	Numbers
i.e	That is	B:C	Benefit cost ratio
PSM	Phosphorus solubilizing microbes	m	meter
S	Significant		
NS	Non-significant		
RNA	Ribonucleic acid		
IAA	Indole acetic acid		
SOD	Super oxidase dismutase		
SEm±	Standard error of mean		
AMF	Arbuscular mycorhiza fungi		
ZSB	Zinc solubilizing microbes		

THESIS ABSTRACT

a) Title of the Thesis	:	Effect of phosphate and zinc solubilizing microbes on profitability and productivity of fieldpea
b) Full Name of the Student	:	Sweety Anant
c) Major Subject	:	Agronomy
d) Name and address of the major advisor :	:	Dr. D.K. Chandrakar Department of Agronomy, College of Agriculture, IGKV, Raipur, C.G.
e) Degree to be Awarded	:	Master of Science in Agriculture (Agronomy)

Signature of the Student

Signature of the Major Advisor

Date:

Signature of Head of Dept.

ABSTRACT

The new research work entitled **"Effect of phosphate and zinc solubilizing microbes on profitability and productivity of fieldpea"** was conducted at Instructional Cum Research Farm, College of Agriculture, Department of Agronomy, IGKV, Raipur during *rabi* season of 2019-20. The experiment was assessed with three replication in Randomized Block Design. The experiment consist of 11 different treatments. Fieldpea as a test crop and variety was Indira matar-1. Recommended dose of nitrogen, potassium and sulphur @ 20 kg ha^{-1} and *Rhizobium* culture applied common to all treatments.

The treatment consist of RDP, phosphorus and zinc solubilizing microbes *viz*. absolute control (T_1), RDP @ 50 kg ha^{-1} (T_2), soil application of 25 kg $ZnSO_4$ ha^{-1} (T_3), application of Biophos @ 5ml kg^{-1} seed (T_4), application of Biozinc @ 5ml kg^{-1} seed (T_5), application of Biophos + Biozinc @ 5ml kg^{-1} seed (T_6), 50% RDP + Biophos @ 5ml kg^{-1} seed (T_7), 12.5 kg $ZnSO_4$ + Biozinc @ 5ml kg^{-1} seed (T_8), 50% RDP + Biophos + Biozinc @ 5ml kg^{-1} seed (T_9), 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc @ 5ml kg^{-1} seed (T_{10}) and RDP @ 50 kg ha^{-1} + nutrient mobilizer (LNm43a) (T_{11}).

The result revealed that use of recommended dose of phosphorus @ 50 kg ha^{-1} and nutrient mobilizer (LNm 43a) was found to be successful and significantly increase the growth and yield attributes of fieldpea rest of the treatments in terms of plant height (cm), number of branches $plant^{-1}$, number of leaves $plant^{-1}$, number of number of pods $plant^{-1}$. Significantly, higher seed yield (1700 kg ha^{-1}) and stover yield (3950 kg ha^{-1}) were also obtained under T_{11} because of the positive interaction between phosphate and zinc solubilizing microbes, they play an important role in boosting crop production by enhancing soil nutrient concentration and making the crop vigoursly develop. Also improved nutrient uptake of NPK in seed and stover . Result also showed that use of RDP + seed treatment with nutrient mobilizers (LNm 43a) also increased the protein yield of fieldpea. Inoculation of phosphate and zinc solubilizing microbes in fieldpea have proven to be the best treatment for achieving the maximum gross realization (Rs 80450 ha^{-1}), net realization (Rs 58234 ha^{-1}) and benefit cost ratio (3.62) under RDP and nutrient mobilizers (LNm 43a). Owing to

improved growth efficiency and yield attributes, yield increases and result in higher economic returns considered as cost effective RDP and microbes

शोधग्रन्थ सारांश

अ) शोधग्रन्थ का शीर्षक : फास्फेट और जिंक घुलनशील सूक्ष्मजीवेां का मटर में लाभप्रदता और उत्पादकता पर प्रभाव

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प्रमुख मार्गदशन के हस्ताक्षर

दिनांक :

विभाग के प्रमुख का हस्ताक्षर

सारांश

नया शोध कार्य **"फास्फेट और जिंक घुलनशाोलता सूक्ष्मजीवों का मटर के लाभप्रदता और उत्पादकता पर प्रभाव"** नामक शीर्षक से निर्दे ाात्मक सह अनुसंसाधन फार्म कृषि महावद्यालय रायपुर के शस्य विज्ञान विभाग इंदिरा गॉधी कृषि वि वविद्यालय रायपुर में 2019 –20 रबी ऋतु के दौरान किया गया। प्रयोग का मूल्यांकन रेंडोमाइज ब्लॉक डिजाइन में तीन पुनरावृति के साथ किया गया था। प्रयोग में 11 विभिन्न उपचार शामिल थे। मटर की किस्म इंदिरा मटर–1 को परीक्षण फसल के रूप में उपयोग किया गया था,राइजोबियम कलचर सभी उपचारों के लिये समान था।

नाइट्रोजन,पोटैशियम तथा सल्फर की अनुशंसित दर 20 किलो प्रति हेक्टेयर था। उपचारो में आरडीपी, फास्फोरस और जिंक घुलनकारी सूक्ष्मजीव शामिल था, जैसे कि पूर्ण नियंत्रण (टी1), आरडीपी 50 किलो प्रति हेक्टेयर (टी2), 25 किलो प्रति हेक्टेयर जिंक सल्फेट का मृदा प्रयोग (टी3), 5 एम एन प्रति किलो बीज की दर से बायोफास का प्रयोग (टी4), 5 मि.ली. प्रति किलो बीज दर से बायोजिंक का प्रयोग (टी5),बायोफास और बायो जिंक का 5मि.ली. प्रति किलो बीज दर से प्रयोग (टी6), 50% आरडीपी और बायोफास का 5मि.ली. प्रति किलो बीज की दर से प्रयेाग (टी7),12.5 किलो जिंक सल्फेट और बायो जिंक का 5 मि.ली. किलो बीज की दर से प्रयोग (टी8), 50% आरडीपी , बायोफास और बायो जिंक का 5 मि.ली. प्रति किलो बीज की दर से प्रयोग (टी9), 50% आरडीपी और 12.5 किलो जिंक सल्फेट और बायोफास और बायोजिंक 5 मि.ली. प्रति किलो बीज की दर से प्रयोग (टी10), आरडीपी 50 किलो पर हेक्टयर और पोषक रूपांतर का प्रयोगएल (एन एम 43a) (टी11)

परिणाम से पता चला कि 50 किलो प्रति हेक्टेयर फास्फोरस की अनुशांसित दर और पोषक रूपांतर (एल एन एम 43a) का प्रयोग दूसरे उपचारों की अपेक्षा प्रभावकारी और महत्वपूर्ण पाया गयाा, पौधे की उॅचाई प्रति पौध, शाखाओं की संख्या प्रति पौध, पतियों की संख्या, प्रति पौधा,` फलियों की संख्या प्रति पौधा, के मामलों में गौरतलब है कि फास्फेट और जिंक की घुलन ाीलता वाले सूक्ष्म जीवाणुओं के बीच सकारात्मकता के कारण उच्च बीज उपज और भूसा उपज भी (टी11) के तहत प्राप्त किया गया था। यह सूक्ष्म जीवाणु फसल उत्पादन को बढ़ाने में महत्वपूर्ण भूमिका निभाते हैं, मृदा में पोषक सघनता को सुधार करके फसल की वृध्दि करते है। साथ ही बीज और भूसा में पोषक तत्वों का अव ाोषण भी बढ़ाते है। परिणाम से यह भी पता चला है कि आरडीपी और पोषक रूपांतर से बीज उपचार का संयुक्त रूप से उपयोग मटर की प्रोटीन उपज को भी सुधारता है। मटर में फास्फेट और जिंक घुलनकारी सूक्ष्मजीवों के संरोपण ने साबित किया कि सबसे ज्यादा सकल आय (₹ 80450/हें), शुध्द आय (₹ 58234/हें) और लाभःलागत अनुपात (3.62) आरडीपी और पोषक रूपांतर (एल एन एम 43a) के अंतर्गत सबसे सर्वोतम उपचार है । विकास और उपज विशेषताओं के बेहतर प्रदर्शन के कारण उपज बढ़ती है और परिणाम स्वरूप उच्च आर्थिक रिटर्न को आरडीपी सूक्ष्म जीवाणुओं के प्रभावी एकीकरण के रूप में माना जाता है।

CHAPTER – I

INTRODUCTION

Pulses are 2nd important cultivated crops after cereals**.** A variety of pulse crops grown in India and world. Among the crops, the major ones are gram, pigeonpea, lentil and fieldpea etc. Pulse crops are grown across the country as sole crop, intercrop, mixed crop, catch crop, relay crop and utera crop, depending upon the agroclimatic conditions of the place where they are cultivated. Pulses are rich in lysine but deficient in S-containing compounds *i.e.* methionine. Globally, dry bean (*Phaseolus vulgaris*) is the most important pulse crop followed by fieldpea and chickpea, respectively.

Pulses form an integral part of the human diet having high fibre content and low glycemic index**.** Pulses are important for the nutritional security point of view. Apart from this, it is consistent source of income and provide employment to small and marginal farmers. The United nation declared 2016 as "International Year of Pulses" with their objective of increasing production and consumption of pulses 10% by 2020. Minimum per capita per day pulse intake recommended by ICAR is 70g.

Rabi season pulses *viz.* chickpea, fieldpea, lentil and lathyrus shares about 42% of global total pulse production. Fieldpea (*Pisum sativum L.)* is a pulse crop that originated in Middle East countries approximately 9000 years ago. Fieldpea is one of the important pulse crops of the world cultivated over an area of about 76.26 lakh hectare. The major fieldpea growing countries are China, Russian Fed, India, Ethiopia and USA. India ranks second in the world in respect of the area (13.89%) after Canada (22%) and occupy fourth position in production (5.36%). Highest productivity is recorded in Ukrain (3126 kg ha^{-1}) followed by Canada (2717 kg ha^{-1}) and Lithuania (2676 kg ha^{-1}). While India productivity is (955 kg ha^{-1}). (Annual Report DPD 2017 -18)

Fieldpea is the most popular pulse crop of India. It is cultivated on 9.34 lakh hectare with a production of 8.88 lakh tonnes during 2017-18. The important fieldpea growing states are Uttar Pradesh, Punjab, Haryana, Rajasthan, Chhattisgarh and Madhya Pradesh. Madhya Pradesh ranks first in India in respect of area (39.81%) followed by Uttar Pradesh (37.47%) and Jharkhand (4.07%) respectively. While in respect of production Uttar Pradesh (41.22%) ranks first followed by Madhya Pradesh (33.27) and Jharkhand (5.16%). The highest productivity was observed in the state of Rajasthan (1858 Kg ha^{1}) followed by Punjab (1333 kg ha^{-1}) and West Bengal (1169 Kg ha^{-1}). The average fieldpea productivity of Chhattisgarh is (431 kg ha^{-1}).

Fieldpea (*Pisum sativum L.)* is the most significant annual cool season pulse crop. It contains rich source of protein (22 %), carbohydrates (62.1%), fat (1.8 %), minerals (calcium - 64 mg $100g^{-1}$, iron - 4.8 mg $100g^{-1}$) and vitamins (Riboflavin, Thiamine**).** Fieldpea is a very popular in India because it contains high level of amino acid lysine and tryptophan. India is the largest producer and importer of pulses. It is also grown for forage crop for cattle. Besides this, fieldpea can be grown as green manure crop which protect the soil from erosion and improves the physical, chemical and biological properties of soil. It is one of the potentially high yielding crop grown in wide varieties of soil types from light sandy to heavy clay. It require cool growing season for its better growth and development. Fieldpea is a short day plant. High humidity is harmful to crop due to incidence of diseases. At flowering and fruiting time the critical temperature range is 15 -18^{o}C.

Fieldpea maintains soil fertility through biological nitrogen fixation in association with symbiotic rhizobium prevalent in its root nodules and thus plays a vital role in agriculture. (Negi *et. al*, 2006). Nitrogen plays a vital role in all living plant tissues. It is essential constituent of proteins, nucleic acid, nucleotide, amino acid, chlorophyll, phospholipid, alkaloids, enzymes, hormones, vitamins etc. It is necessary for imparting dark green colour to plant, for improving quality and succulence to fodder crop. The content of N in healthy plants ranges between 1-5% upon the species.

Phosphorus is essential constituent of nucleic acid, phytin, phospholipids, ADP (Adenosine di-phosphate) and ATP (Adenosine tri-phosphate) act as energy currency. It is also an essential constituent of majority of enzymes which play significant role in the transformation of energy in carbohydrate metabolism, fat metabolism and also help in respiration of plants. It is essential for growth and development of reproductive parts, *i.e.,* fruit and seed. Heavy concentration in meristematic region of actively growing parts of plant. It stores and transfer energy and increased plant growth. It increases root to shoot ratio. In legumes, increase N fixation capacity by enhancing the activity of rhizobia and nodules. In cereals, increase straw strength. It increase plant tolerance to root rot disease and also responsible for early maturity of seed and fruit (N delay maturity). Deficiency of phosphorus caused stunning of plant and dark green colouraion of older leaves. Purple colouration of leaves and leaf edges in maize and grasses due to sugar accumulation that enhance anthocyanin synthesis.

There are large reserves of phosphorus in soils but very little amount is available to the plant. There are microorganism that can solubilize the unavailable soil phosphorus and make it available to plants. They are called Phosphate solubilizing microbes (PSM). Phosphate solubilizing microbes include various bacterial, fungal and actinomycetes forms which help to convert insoluble inorganic phosphate into simple and soluble form. Members of Bacillus, Pseudomonas, Micrococcus, Flavobacterium, Penicillium, Fusarium, Sclerotium and Aspergillus are some of the phosphate solubilizing microbes. These microorganism were found to mineralize organic phosphorus to soluble form due to enzymatic activity.

The majority of agricultural soils contain large reserves of phosphorus of which considerable part has accumulated as consequences of regular application of P-fertilizer. The phenomenon of fixation and precipitation of P in soil, which highly dependent on pH, causes a low efficiency of soluble P-fertilizers. In acidic soil, P is precipitated as Al and Fe phosphate whereas in calcareous soils high concentration of Ca results in P precipitation. The soil is habitat for diverse group of organisms that employ variety of solubilization reaction to release soluble phosphorus to insoluble phosphate. The potential of these phosphate solubilizing microorganism has been realised and are utilized as bioinoculants for crop grown in soils poor in available P and amended with rock phosphate. Factor affecting P fixation are soil mineral, soil pH, soil organic matter, cation and anion effect and temperature

Potassium is important macronutrient. It is essential for activating enzymes (starch synthetase and nitrogenase enzymes) concerned in the synthesis of polypeptides from amino acid and it is also essential for the process of photosynthesis and respiration. It maintain the ionic strength of plant cell. It involved in water relation, osmotic pressure and charge balance in plant cell and across the membrane. It is important for qualitative character of the plant since it is needed for synthesis and transportation of photosynthates to storage plant parts (sink). Highest concentration found in meristematic region and imparts disease resistance in plants. It increase shoot to root ratio.

Zinc is essential micronutrient which is required in small quantities for proper growth and development of plant. Zinc is constituent of carbonic anhydrase, RNA polymerase enzymes, important in synthesis of IAA (Indole Acetic Acid) and essential for water uptake. It help in production of SOD (Super oxide dismutases) which control oxidative stress in plants. Zinc solubilizing bacteria are mainly belongs to genus of Bacillus which have efficiency to solubilize zinc from insoluble form by secretion of some organic acids and it can be utilized to increased zinc availability to crop. Deficiency of zinc cause intervenial chlorosis of middle leaves, short stem internode, stunted plant and rosette leaves due to auxin inhibition, sometimes malformation of leaves as well as fruits of occurs. Khaira disease also occur in rice due to deficiency of zinc in rice. Factor affecting zinc availability in soil are soil pH, adsorption, soil organic matter and interaction with other cation etc. A dominant transport mechanism of zinc is diffusion.

Zinc solubilizing microbes like Pseudomonas, Bacillus, Acetobacter, Gluconacebacter, Thiobacillus and Rhizobium play significant role in zinc solubilizaton and it is essential for optimum plant growth. These microbes have high potential in transforming fixed zinc into available forms through various mechanism such as acidification, organic acid production like cyanic, ferruginc acid etc. by declining the pH of soil. These microbes also produce various phytohormone like IAA (Indole Acetic Acid) which is directly involve in growth and development of plant. Zinc solubilizing microbes are highly responsible for phytoextraction (rhizoremediation) in the region where concentration is high cause toxicity through the production of organic acids and enhance the availability in the region where concentration is below because toxicity reduced root growth, yellow leaves and death of plants.

Hence keeping the above fact in view a field study on **"Effect of phosphate and zinc solubilizing microbes on profitability and productivity of fieldpea"** was conducted at Instructional Cum Research Farm IGKV, Raipur during rabi season of 2019 - 20 with the following objectives :

- To study the effect of phosphorus and zinc solubilizing microbes on growth, yield attributes and yield of field pea.
- To study the effect of phosphorus and zinc solubilizing microbes on quality of field pea
  .
- To find out the economics of different treatments.

CHAPTER – II

REVIEW OF LITERATURE

Fieldpea is being an important pulse crop and are considered as reliable pulse crop, particularly in deficient rainfall areas. Fieldpea are grown both as grain for human consumption, forage for cattle and also as green manuring crops to provide nitrogen. Fieldpea is grown as component of a cropping system. Hence, keeping above idea in view of fieldpea, an attempt has been made in this chapter to provides review of work done by various agriculturist in India and abroad which have been collected and represented here in following heads :

2.1 Phosphate solubilizing microbes

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2.2 Zinc solubilizing microbes

2.2.1 Effect of zinc solubilizing microbes

2.2.1.1 Growth parameters

2.2.1.2 Nodulation

2.2.1.3 Yield attributes and yield

2.2.1.4 Nutrient uptake

2.2.1.5 Economics

2.1 Phosphate solubilizing microbes

2.1.1 Effect of phosphate solubilizing microbes

2.1.1.1 Growth parameter

Rudresh *et al.,* (2005) reported that combined inoculation of Rhizobium and Phosphorus solubilizing bacteria and Trichderma spp. show positive interaction in obtaining highest yield in chickpea by improving the growth and development of plant at all stages from germination to maturity stage. They observed this three microorganism play very important role in increasing germination rates, nutrient uptake, no of branches, plant height, no of nodules and seed yield.

Ganie *et al*., (2009) reported that effect of combined inoculation of biofertilizers gave superior result in promoting growth and yield of gardenpea than applying alone. Intergation of Rhizobium + Acetobacter + PSB increase nutrient concentration of N, P, K due to biological nitrogen fixation and enhance the growth of plant in terms of plant height (45.26 cm), no of leaves (13.33), no of branches (2.67), no of nodules (44.46), fresh weight (612.34 mg) and dry weight (172.62 mg) of nodules and also maximum yield in terms of pod length (9.69 cm), no of pod plant^{-1} (19.37), no of seed pod^{-1}(8.22) and yield of pod (74.24 qn ha^{-1}).

Khan *et al.,* (2009) reported that synergistic effect of phosphate solubilizing microbes on improving the crop productivity in terms of growth attributes and yield attributes. They found the positive interaction between phosphate solubilizing microbes and crop plant. Phosphate solubilizing microbes help in mineralization of phosphorus in soil through various mechanism such as organic acid production which increase the phosphorus availability in soil and phosphorus uptake by plant and also release phytohormone IAA (Indole Acetic Acid) which is directly involve in the growth and development of plant and ultimately contribute to crop yield.

Kuhawat *et al.,* (2009) reported that combined application of organic maunres, inoculation of phosphorus solubilizing bacteria (*Bacillus polymyxra*) and phosphorus fertilization were helpful in enhancing growth of plant in respect of plant height, no of branches, no of nodules, fresh weight, dry weight, nodule weight and finally seed yield (8.09 q ha^{-1}) of mungbean..

Rather *et al.*, (2010) found that co-inoculation of Rhizobium + Azotobacter + PSB in fieldpea gave beneficial result on higher plant growth in terms of plant height (45.26cm), no of branches $plant^{-1}$ (4.20), no of leaves $plant^{-1}$ (13.33), no of nodules $plant^{-1}$ (38.46), dry and fresh weight of nodules (122.62 and 562.34 mg). Co-inoculation of biofertilizers also enhance yield attributes like pod length, no of pod $plant^{-1}$, no of seed pod^{-1} gave promising result in respect of seed and straw yield.

Mishra (2014) reported that positive effect of integration of biofertilizers with chemical fertilizer on soil fertility status of fieldpea which improved all the growth, yield attributes and grain yield upto 31 q ha^{-1} by inoculating PSB, Rhizobium, PGPR which are efficient and effective alternative to phosphate fertilizers.

Meena *et al.*, (2015) reported four strains of phosphorus solubilizing bacteria from root nodules of field pea. They reported that these phosphorus solubilizing bacteria survive in low temperate condition possess resistant to cold, also have potential to solubilize insoluble form of phosphorus into available form. Thus, decline the pH of soil which increase availability of phosphorus in plant. Besides this, microbes are also responsible for releasing phytohormone IAA (Indole acetic acid) in soil which is directly involve in growth of plant in terms of plant height, no of leaves $plant^{-1}$, no of branches $plant^{-1}$, no of pod $plant^{-1}$, no of seed pod^{-1}, dry matter yield and seed yield. They also found that, these phosphorus solubilizing microbes release phytohormone IAA (Indole acetic acid) 62.7 - $198.1mg^{-ml}$.

Oteino *et al.*, (2015) reported that ability of phosphorus solubilizing bacteria endophytic *Pseudomonas* for producing gluconic acid, helpful in solubilizing insoluble phosphate into soluble phosphate and stimulate plant growth in term of plant height, no of leaves $plant^{-1}$, no of branches $plant^{-1}$, no of pod $plant^{-1}$, no of seed pod^{-1}, dry matter yield and seed yield by releasing phytohormone like IAA (Indole Acetic Acid), cytokinin in *Pisum sativum.* The result indicate this endophytic *Pseudomonas* produce gluconic acid (14-169 mM) and have moderate to high phosphate solubilization capacity.

Zaghloul *et al.,* (2015) found that uses of biofertilizer (*Rhizobium leguminosarum, Glomus bagyarajii* and *Bacillus circulan*s), foliar application of micronutrients, yeast extract (*Saccharomyces cereviseae*) and chemical fertilizers (NPK) as RDF in fieldpea. Effect of this Intergrated Fertilization Management improve the plant growth and production by enhancing the nitrogenous activity on nodules which increase numbers of nodules plant^{-1} and also N and P content in soil.

Kothyari *et al*., (2017) conducted experiment on effect of biofertilizer is superior on plant growth and seed yield of fieldpea. He found that application of 100% RDF + Rhizobium 200gm seed^{-1} enhanced higher seed yield and yield attributes in fieldpea by increasing plant height (50.65cm), numbers of branches plant^{-1} (13.75), numbers of leaves plant^{-1}, days to 50% flowering (49.33), no of pods plant^{-1}, days to maturity (81.00) and nodules plant^{-1}(21.95).

Sistani *et al.,* (2017) found that effect of inoculation of *Rhizobium leguminosarum* in fieldpea decreased most common fungal diseases ascochyta blight which is caused by *Disymella pinodes* and symbiotically enhanced yield through increasing seed yield, fresh weight and dry weight .They also found that pathogen *D. pinodes* reduced the colonization of root nodules and thus, seed infection. However, these rhizobium induces several protein which degrades carbohydrates, and adjust the cell wall. Therefore, helpful for seed synthesis during diseases control.

Kalayu. (2019) reported that phosphorus solubilizing microorganism belong to genus Bacillus, Pseudomonas and Rhizobium have possess the ability to increase crop production by enhancing the growth attributes such as height, no of leaves plant^{-1}, no of branches plant^{-1}, no of nodule plants^{-1}, fresh weight and dry weight of nodules and also maximum yield in terms of pod length, no of pod plant^{-1}, no of seed pod^{-1}and yield of pod. These microorganism play important role in boasting the productivity of crop through various strategies and it also reduce use of chemical and toxic fertiltizer which is directly involved in environmental pollution by it long term residual effect on soil cause deficiency of several nutrient in soil.

Sani *et al*., (2019) reported that some of bacteria belonging to genus Bacillus, Enterobactor not only promote growth, yield of plant but also control disease like black pod disease caused by *Phytopthora megakarya*. These phosphate solubilizing bacteria solubilize insoluble form of phosphorus into soluble form of phosphorus through production of organic acid enhance the plant height, total dry mass, no of leaves plant^{-1}, diameter of stem of cocoa tree.

2.1.2 Nodulation

Mishra and Prasad (2010) found significantly recorded maximum number of nodules at 30 DAS (9.33), 45 DAS (29.50) and 60 DAS (46.92). They also found that maximum nodule dry weight at 30 DAS (4.24 mg), 45 DAS (34.69mg) and 60 DAS (64.38 mg) is mainly due to increased bacterial population around rootzone in dwarf fieldpea. This showed that more nutrient uptake by the plant increased P-availability which enhance nodules formation in root zone. Thus, increase in nodulation, grain and straw yield increased by combined inoculation of Rhizobium + PSB + PGPR by 19.06% and 30.62% over Rhizobium, 19.06% and 30.62% over PSB and PGPR alone inoculation.

Singh *et al.,* (2012) revealed in their experiment that SSP and PSB application in fieldpea is more superior than DAP and AMF (Arbuscular mycorrhizal fungi) application in respect of highest nodulation, yield attributes, protein content, N and P uptake. They also found that SSP and DAP application in fieldpea have residual effect on growth and development of rice enhance grain yield due to effective tillers, grain and straw yield. This increment due to higher amount of N-fixation besides better P availability. Inoculation of fieldpea with AMF also have significant residual effect on rice as compared to PSB as AMF produces spores (zygospores and chlamydospores) which regerminate but PSB are not able to tolerate submergered condition and becomes less capable. And they also concluded that 100% P as basal + 50% P as top dressing at branching initiation stage through SSP and PSB inoculation enhance fertility status of soil, by increasing phosphorus use efficiency. Thus, improved the productivity and net return in fieldpea and its residual effect on rice

Tagore *et al.,* (2013) reported highest production in chickpea through inoculation of Rhizobium and Phosphorus solubilizing bacteria belong to *Pseudomonas striata, Bacillus megatarium, Bacillus polymyxra* etc. directly responsible for the growth and development of plant in terms of growth parameters and yield parameters like nodule number, nodule weight, fresh weight, dry weight, shoot dry weight, leghaemoglobin content and seed and straw yield. They conducted trails of five chickpea genotypes IG-226, IG-370, IG-379, JG-412 and IG-593 (no inoculum, Rhizobium inoculum, PSB inoculam and Rhizobium + PSB inoculam) and found that combined inoculation of Rhizobium + PSB show higher nodules number (27.66 nodules plant^{-1}), nodules fresh weight (144.90 mg plant^{-1}), nodule dry weight (74.30 mg plant^{-1}), shoot dry weight (74.30 mg plant^{-1}) and leghaemoglobin content (2.29 mg g^{-1} fresh nodules) and ultimately show benefit effect on straw and grain yield.

Teli *et al*., (2015) reported that combination of 100% RDF + PSB + Rhizobium inoculation were found effective significantly increased plant height (74.13cm), chlorophyll content of leaf (2.453mg^{-1} g), pod length (8.11cm), fresh weight (6.75g), green pod yield (5.5kg plot^{-1}), grain yield (37.59 kg ha^{-1}), total nutrient uptake (191.37 kg ha^{-1}) and phosphorus uptake by grain (17.79 kg ha^{-1}).

Rani *et al*., (2018) reported that combined application of organic and inorganic sources of nutrient improved overall growth, yield attributes and yield of fieldpea. After inoculation, Rhizobium increase nitrogenous activity and fix atmospheric N due to increase in nodulation. Thus, result in increased dry weight, N content, and seed yield.

Singh *et al.,* (2018) reported that use of biofertilizers *viz.* Rhizobium, PSB show significant result on growth and proper development of chickpea by increasing nodulation which enhance the nitrogenous activity in root zone stimulate phytohormone cause considerable increase in plant height, no of branches plant^{-1}, no of pod plant^{-1}, no of seed plant^{-1} which is essential for the enhancing the productivity.

2.1.3 Yield attributes and yield

Ahmed *et al.,* (2007) reported that when plant receive both seed and soil inoculation of Rhizobium strain BARI RPs - 2001 performed best and improved no of pods plant^{-1}, no of seed pods^{-1}, 1000 seed weight, pods and seed yield . It also showed positive relation among protein content, seed and pod yields of fieldpea considered as an effective alternative for achieving maximum output in shallow red brown terrace soil. This report indicate different method of Rhizobium inoculation gave synergists effect on pod length, no of seeds plant^{-1} and ultimately maximize the output.

Elkoca *et al.,* (2007) reported that impact of inoculation of Rhizobium and P solubilizing bacteria *Bacillus megaterium* and *Bacillus subtiles* in chickpea is more effective than any other chemical nitrogen, phosphorus fertilizers significantly improved the plant height, no of branches plant^{-1}, no of pods plant^{-1}, shoot weight, dry weight, nodules weight, no of seed pod^{-1} and contributes to higher yield.

Ramana *et al.,* (2010) found that effect of biofertilizer (VAM , PSB) and inorganic fertilizer on growth, yield and quality of French bean. They observed that superiority on plants in terms of plant height, no of branches plant^{-1}, leaf area , dry weight, no of pod plant^{-1}, no of seed pod^{-1}, pod length, 100 seed weight by co-inoculation of VAM @ 2kg ha^{-1} + PSB @ 2.5 kg ha^{-1} + 75% RDF.

Khanna *et al.*, (2012) suggested that use of native P- solubilizing rhizobia (R_1 and R_2) induced number of root hair and root laterals which facilitate better uptake of nutrients by fieldpea increase P- availabilty in the soil which increase plant biomass and positively associated with yield potential of fieldpea.

Pramanik and Bera., (2012) found positive response on growth and yield of chickpea by using biofertilizers viz. Rhizobium, PSB and VAM help in biological N-fixation, dissolve insoluble form of phosphorus in soil and enhance the mobility of element in plant in available form. The results show that increase in no of branches plant^{-1}, no of pod plant^{-1}, no of seed plant^{-1}, test weight, grain yield, stalk yield and harvest index. .

Hyder *et al.,* (2016) found that combination of biofertilizer + vermicompost + chemical fertilizer have positive interaction in enhancing the yield of pea. They recorded maximum pea yield (3.9 t ha^{-1}) due to significant increase in nodule number, root length, shoot length, nutrient and protein content of pea. They confirmed that application of Biozote + Vermizote 1tn ha^{-1} + 75% of RDF superior than other combination for optimizing production without additional cost of expensive fertilizer. Thus, the use of bio-organic source have capability to enrich the soil with all the nutrients and make available to the plant for increasing growth and proper development of plant for sustainable production.

Nadeem *et al.,* (2017) reported that combined seed inoculation of Rhizobium and PSB along with application of 40 kg P ha^{-1} improved the growth parameter *viz.* plant height, total dry matter (13.91g plant^{-1}), pod yield (196.37 g plant^{-1}), nutrient status like available N (370.89 kg ha^{-1}),P (38.57 kg ha^{-1}), K (168.77 kg ha^{-1}) and yield attributes of cowpea during summer season by enhancing the fertility of soil and ultimately productivity

Alori *et al.,* (2017) revealed that use of phosphate solubilizing microbes improve crop production without causing harmful effect on environment and also reduce the use of chemical fertilizers in soil. They suggested that soil microorganism enhance the nutrient availability in soil and thus plant can taken up. Inoculation of phosphate solubilizing microbes solubilizes insoluble form of phosphoru into soluble form of phosphorus. On average, 0.05% phosphorus content in soil, only 0.1% of this phosphorus is available (Zhu *et al.*, 2011), this cause deficiency of phosphorus in soil, to overcoming this deficiency PSB should be used as bioinoculant. Many species belong to *Bacillus megaterium, Bacillus circulans*, *Bacillus subtiles* and Pseudomonas striata are important phosphate solubilizing microbes.

Pandey *et al*., (2017) reported that combined application of manures (FYM and Vermicompost), biofertilizers (Rhizobium and PSB) and inorganic fertilizers

(100% NPK) in fieldpea gave positive effect on seed yield and its attributes. Intergrated Nutrient Management experiment show synergistic effect on P solubilization and make available to the plant due to the activity of microbes which significantly increased the no of branches, plant height, root nodulation and development and make the plant to grow vigourously and accumulate higher amount of dry matter and seed yield.

Islam *et al.,* (2019) reported that effect of arbuscular mycorrhiza fungi in fieldpea provides higher seed yield were inconsistent in subsequent cropping yield. They considered 3 factor soil, site and inoculation to know the influence on seed yield. Found that successful AMF symbiosis depend on soil properties, climatic factors and native AMF composition.

2.1.4 Nutrient uptake

Rodriguez and Vidal (2000) reported that phosphorus solubilizing bacteria belong to Pseudomonas, Bacillus and Rhizobium possess vast ability in dissolving insoluble form of phosphorus by production of organic acid like fumaric, succine, glutamic, tartaric, oxalic, lactic and alfa- ketobutyric acid which is directly involve in mineralization process and thus, increase the availability of phosphorus and nutrient uptake in plant.

Daniel *et al.,* (2009) reported that inoculation of phosphate solubilizing microbes increase the grain yield of crops. These are known to add 30-35 kg P_2O_5 ha^{-1} , reduce the use of expensive fertilizers and overcome the deficiency of nutrients in soil by declining the pH of soil. Thus, enhance the nutrient availability and nutrient uptake by plant which is responsible for promoting growth in plant at all growth stages through release growth promoting hormones like IAA, gibberalin etc .

Khan *et al.,* (2009) reported that effect of phosphorus solubilizing bacteria play important role in crop productivity. Phosphate solubilizing bacteria are members of Pseudomonas, Bacillus mainly. These microbes help in solubilization of insoluble phosphorus into soluble form through mechanism like organic acid production by declining the pH of soil which increase the nutrient availability of soil and nutrient uptake of plant.

Mcland *et al.,* (2009) reported that many species belong to *Bacillus megaterium, Bacillus circulans, Bacillus subtiles* and *Pseudomonas striata* are important phosphate solubilizing microbes. These are microorganism in soil that can solubilize the unavailable phosphorus and make it available to the plant. Many group of fungi associated with the roots of higher plant mobilize the phosphorus from to the plant system. These microorganism are used as bioinoculant for crop grown in soil poor in available phosphorus.

Miller *et al.,* (2009) reported most efficient bacterial isolates were identified as *Pseudomonas striata, Pseudomonas rathonis* and *Bacillus polymyxa* and fungal isolates as *Aspergillus awamori, Penicilliun digitium* and *Aspergillus niger*. These efficient microorganism have showed consistently their capability to solubilize chemically fixed soil phosphorus and rock phosphorus from different sources. In addition, these microorganism were found to mineralize fixed phosphorus into soluble form due to enzymatic activity.

Vyas *et al.,* (2009) conduct an experiment of 19 phosphate solubiling bacteria belong to *Pseudomonas fluroscene, Pseudomonas poae, Pseudomonas trivialis,* and *Pseudomonas spp.* to know the ability of organic acid production during phosphorus solubilization process which is directly responsible for solubilization of insoluble form of phosphorus into soluble form and thus improve the plant growth. The result show that different strains have different ability in producing organic acid irrespective of genetic relatedness.

Baig *et al.,* (2010) reported that phosphorus solubilizing microbes have vast potential to solubilize insoluble form of phosphorus into soluble form of phosphorus through the production of organic acid in soil. Based on quantitative method, they conduct the experiment for measuring the solubilization of phosphorus by phosphorus solubilizing microbes and compared this solubilzation by qualitative method of solubilizing phosphorous. They suggested quantitative method si better than qualitative method for identification of potentially efficient phosphate solubilizing microsolubilizers.

Khan *et al.,* (2010) reported that phosphorus solubilizing fungi play important role in promoting growth of plant by dissolving phosphorus which is abudant in soil in both form organic and inorganic but not available to plant cause deficiency of phosphorus in plant and later impact on crop productivity.

Bhat *et al.,* (2013) reported that synergistic interaction between phosphorus and bio-fertilizers. They found that integrated application of phosphorus and combined application of Rhizobium and PSB have significant effect on solubilizing the insoluble phosphorus and make available to the plant which result in more uptake of N, P and K thus increasing protein contain, enriching the soil fertility and boasting the productivity of fieldpea.

Anand *et al.,* (2015) reported that phosphorus solubilizing microbes (*Pseudomonas*, *Mycobacterium, Micrococcus, Flavibacterium*) play important role in proper growth and development of plant as phosphorus is macronutrient involve in energy transfer and protein metabolism. These microbes help in mineralization of the insoluble form of phosphorus into available form so plant can utilize this form effectively.

Omar *et al.,* (2015) reported that various mechanism of phosphates solubilzing bacteria which are very helpful in dissolving insoluble form of phophorus into soluble form of phosphorus through production of organic acid in soil by reducing the pH of soil and enhance nutrients availability in soil. Other mechanism is production of siderophores in soil which dissolve the fixed phosphorus in soil thus increase the availability in soil and nutrient uptake in plant contributes to the proper plant growth and development and ultimately maximize the yield.

Sharma and Thakur (2016) reported that combined inoculation of biofertilizers (Rhizobium and PSB) with reduced doses of inorganic fertilizers (25-50%) improve the fertility of soil and increase the potential of production without the damaging the environment. Use of biofertilizers improve the soil properties and nutrient content through solubilizing insoluble phosphorus into soluble form. Besides these, it reduces the requirement of chemical fertilizer which have deleterious effect on physical, chemical and biological properties of soil and focussing to ecofriendly environment with boasting the production to fulfill the needs of raising population.

Saritarani *et al.,* (2016) reported that seed inoculation with biofertilizer is directly related to grain productivity. They found that combined inoculation of Rhizobium + PSB + PGPR + RDF in fieldpea enhance the nodule development, biological N fixation, also nutrient uptake of K and Zn. They also recorded significantly increases in fresh weight, dry weight, straw and grain yield of fieldpea and also revealed that application of biofertilizers with chemical fertilizer improve overall growth of fieldpea due to highest energy use efficiency.

Billah *et al.,* (2019) revealed that phosphorus is important mineral element and occupy as significant macro nutrient in maintaining the growth of plant .To fulfill this requirement, Phosphorus solubilizing microbes should use to make up deficiency of P as it is fixed in soil and it is only way to solubilize the insoluble phosphorus by adopting various mechanism through PSM such as release of organic acids etc

2.1.5 Economics

Mishra. (2014) reported that highest net return was recorded in snow pea (*Pisum sativam var. microcarpan L.*) at 100% recommended dose of chemical fertilizers combined with vermicompost and biofertilizers in presence of lime. This might helped in increased vegetative growth, protein content due to high supply of nitrogen and phosphorus to growing plants. Due to better performance of yield attributes which increase yield and result in higher economic returns considered as cost effective combination of organic and inorganic nutrient sources.

Kumar *et al.,* (2016) recorded the highest yield (2900 kg ha^{-1}) in fieldpea with the application of vermicompost 1t ha^{-1} + FYM 5 t ha^{-1} + 50 % RDF inoculated with rhizobium culture in Bundelkhand region. This integrated nutrients management play significant role in improving soil fertility status by increasing amount of N fixation and enhancing P availability to the plant which significantly increase the plant height, branches $plant^{-1}$, pod length, pod $plant^{-1}$, pod weight $plant^{-1}$, 1000 seed weight and ultimately seed yield.

Samborlang *et al.,* (2019) reported that application of organic nutrient in addition to inorganic nutrients in vegetable pea gave beneficial effect on grain yield of succeeding crop of maize in North eastern hill of Meghalay. The result show that incorporation of RDF + lime 0.5 t ha^{-1} + Rhizobium + PSB + FYM 5 t ha^{-1} in preceeding crop of vegetable pea have significant effect on residual fertility of soil as higher nodule formation of pea. They found the positive interaction of organic and inorganic sources of nutrients brought maximum grain yield and stover yield, gross returns, net returns and B :C ratio in maize as influence in yield attributes *i.e* maximum number of cob $plant^{-1}$, high kernel weight $plant^{-1}$ and dry matter accumulation.

2.2 Zinc solubilizing microbes

2.2. Effect of zinc solubilizing microbes

2.2.1. Growth parameter

Iqbal *et al.,* (2010) reported that effect of phosphorus and zinc solubilizing bacteria on all the growth attributes of mungbean in terms of maximum root length, shoot length, fresh weight and dry weight of mungbean due to increase solubilization of insoluble phosphorus and zinc by microorganism which are utilized by plant to improve growth and production.

Goteti *et al.,* (2013) reported that zinc solubilizing bacteria optimize the growth of maize in respect of increase in root weight, dry mass and increase nutrient uptake of zinc in soil by solubilizing the zinc present in insoluble form in the presence of bacteria which is used as bio input and as a substitute for chemical fertilizer.

Joshi *et al.,* (2013) identified the soil microbes present in the rootzone of rice belong to Pseudomonas family have potential to solubilize insoluble form of phosphorus, zinc oxide and zinc sulphate by various mechanism like acidification and production of siderophores. They observed that application of these microbes increase the plant height, chorophyll, grain number in wheat. Thus, increase in yield and also zinc content in grain. Also found that oxalic, malic, ketuglutaric and fumaric acid in rootzone of wheat helped in mobilization of insoluble form of zinc from soil to plant. Valine, leucine, sugar, protein and phenol etc are also present in root exudates of wheat.

Vaid *et al.,* (2014) isolated that zinc solubilizing bacteria (belong to the genera Burkholderia and Acetobacter) and found that highly responsive for promoting growth by enhancing nutrient uptake of zinc in zinc deficient soil of rice and favour maximum no of tillers plant^{-1}, dry matter, no of panicle plant^{-1}, no of grain panicle^{-1}, grain and straw yield.

Naaz *et al.,* (2016) reported that combined inoculation of biofertilizers viz. Rhizobium, Azosprillium and Pseudomonas along with chemical fertilizer significantly increased the nutrient uptake *viz* zinc at all the growth stages of plant, improve the soil fertility and the quality of produce over chemical fertilizer alone.

Sharifi (2016) reported that application of biofertilizer and zinc increases oil and protein content in soybean. He found that inoculation of biofertilizer *Bacillus japonicum* in soybean increases no of pod plant^{-1}, no of grain pod^{-1}, nodule weight, oil content, protein content and also fatty acid linoleic acid by declining saturated fatty acid like palmitic and steric and ultimately enhance the yield.

Kamran *et al.,* (2017) reported that zinc solubilizing microbes *viz. Pseudomonas fragi, Pantoea agglomerans, E.cloace and Rhizob*ium sp. show beneficial effect on growth parameters of plant in terms of root length, shoot length , root dry weight as stimulating zinc content in soil.

Mishra *et al.,* (2017) reported that zinc solubilizing bacteria belonging to genus *Pseudomonas aeruginose, Ralstonia picketti, Burkholderia cepacia* and *Klebiella pneumoniae* from rootzone of rice. They revealed that this zinc solubilizing bacteria mineralize insoluble form of zinc into soluble form but effectively solubilized zinc oxide as compared to zinc carbonate form of zinc. While pH of soil is also declined due to microbial activity in the root zone and also responsible for release of plant growth promoting hormone which directly involve in growth and development of plant.

Shaikh and Saraf (2017) isolates four bacterial and fungi strain show PGPR characteristic. These soil microbes promotes growth in plant by direct or indirect mechanism, also increase the availability of nutrient in soil like nitrogen, phosphorus and zinc and producing many phytohormones like auxin, gibberellin specially involve in the growth and development of plant and thus maximize yield.

Fatima *et al*., (2018) reported that effect of inoculation of zinc solubilizing bacteria (Bacillus sp.) on growth and yield of okra (*Abelmoschus esculentus L*.). Zinc solubilizing bacteria *Bacillus aryabhattai* significantly increase growth attributes in terms of plant height (30%), shoot fresh weight (19%), dry weight (66%), root length (79%), root fresh weight (58%), root dry weight(66%), no of fruits (69%) through improving the soil fertility by enriching the soil N 20%, P 65%, K 20%and protein 20% .Thus, increase in yield and production.

Deshmukh *et al*., (2019) reported that zinc solubilizing bacteria (ZSB) and zinc solubilizing fungi (ZSF) play important role in mineralization of zinc in soil. They conduct the experiment and found the capability of both the microbes in sugarcane crop by inoculation of both the microbes with grade dose of fertilizer. The result indicated that both zinc solubilizing fungi and zinc solubilizing bacteria have pronounced effect on growth and yield of sugarcane. These is due to synthesis of phytohormone IAA, gibberalin, cytokinin, and zeatin which are highly responsible for promoting growth at all the stage. And they also suggested that highest solubilizing potential of ZSB as carrier based bio-formulation and ZSF as liquid bio-formulation should be used.

2.2.2 Nodulation

Ullah *et al.*, (2019) found the positive effect of zinc solubilizing endophytic bacteria on profitability and productivity of Kabuli chickpea. Inoculation of bacteria improved the zinc availabilty in soil by mineralization of insoluble form of zinc. Thus, increase the soil nutrient status which enhance the crop growth and productivity in terms of maximum nodulation, leg-haemoglobin, grain yield and grain quality.

2.2.3 Yield attributes and yield

Zuo and jhang (2009) reported that intercropping of dicot with graminaceous crop is more effective than monocropping along with zinc and iron biofortification to combact zinc deficiency in food. They found that increase in root growth and result in high transfer of iron and zinc from soil to plant due to intercropping increases microbial diversity.

Albaid-Ullh and Hafiz (2014) found that zinc mobilizer bacteria *Serratia* sp. have capacity to solubilize insoluble form of zinc present in the soil by various mechanism such as acidification and production of organic acid beneficial for the growth parameter of crop and contribute to higher production.

Kumar *et al.,* (2014) reported that application of FYM and zinc solubilizer (Bacillus sp.) increase dry matter yield and curcumin content of turmeric. It also improved nutrient status of soil by enhancing the macronutrient potassium and also micronutrient copper and manganese brought by biofortification of zinc and iron.

Ramesh *et al.,* (2014) reported that inoculation of zinc solubilizing bacteria *Bacillus aryabhattai* have beneficial effect on the growth of maize and soybean by enhancing the nutrient uptake, especially zinc which improve the availability of soil zinc by solubilizing inorganic forms of zinc.

Hussain *et al*., (2015) islolates ten strain of zinc solubilizing bacteria and found that *Bacillus sp* maximize the yield by increasing the zinc availability in soil through dissolving the insoluble form of zinc and enhance the availability in soil which promote the growth of maize seedling and significantly maximize the yield

Naaz *et al*., (2016) reported that inoculation of biofetilizer viz. Azosprillium, Pseudomonas and Rhizobium on wheat improve yield potential by increasing the rates of growth at all the stages of plant. These biofertilizer makes the soil productive by increasing nutrient status of soil and also have potential to increase zinc content in plant.

Mumtaz and Hussain (2017) found that zinc solubilizing bacteria *Bacillus subtilis* and *Bacillus aryabhattai* is helpful in promoting growth in maize seedling by enhancing growth parameter of the crop which incresase the availability of zinc in zinc deficient soil and thus, improving the productivity.

Dinesh and Vidya (2018) reported that zinc solubilizing bacteria *Bacillus megaterium* improve zinc content in soil by solubilizing insoluble form of zinc into available form and increase the pH of the soil with the production of gluconic acid .Thus, this microbes have high potential in promoting crop growth and are utilized as bioinoculants for crop grown in soils poor in available zinc.

2.2.4 Nutrient Uptake

Saravanan *et al*., (2011) reported that zinc solubilizing microbes are highly responsible for phytoextraction (rhizoremediation) in the region where concentration is high cause toxicity with the production of organic acids and enhance the availability in the region where concentration is below.

Bapiri *et al.,* (2012) reported zinc solubilizing bacteria show higher capability in dissolving different form of zinc from insoluble form of zinc through various mechanism. The experiment conducted in broath and media for knowing the ability of zinc solubilizing bacteria *Pseudomonas fluorescent*. After inoculation of 5 days, concentration of zinc for zinc oxide is 28-625 mg^{-1} at pH change from 7.0-7.2 to 3.5-6.3 and the concentration of zinc for zinc carbonate is 247-753 mg^{-1} at pH change from 7.0-7.2 to 3.5-6.3.

Desai *et al.,* (2012), reported that both macro and micronutrient is essential for optimum growth of plant. They found that microorganism have capability to mobilize more than one nutrient in soil which are fixed in soil matrix. Inoculation of *Acetobactor, Azospirillum, Bacillus* and *Rhizobium* in crop solubilize insoluble form of nutrient like zinc as zinc oxide (ZnO), phosphorus as tricalcium phosphate (TCP) by declining the pH of soil. These microbes release highest amount of ZnO (16.3 ppm) and phosphorus (14.8ppm). Hence, in these ways crop are supplemented by both the essential nutrients by microorganism.

Nyoki *et al.,* (2014) reported that inoculation of biofertilizer *Bradyrhizobium japonicum* in cowpea increase the uptake of micronutrients especially zinc, iron, manganese and copper. This microbes improve the soil micronutrient availability by mineralization of organic micronutrients essential for the plant growth and development of plant and ultimately contribute to higher yield.

Imran *et al.,* (2014) reported that use of soil microbes is helpful in improving the availability of zinc by increasing nutrient uptake in soil. Thus, play significant role in promoting growth in plant. However, these micobes have high potential in dissolving insoluble micronutrient into soluble form and make available to the plant.

Panwar *et al.,* (2015) reported microorganism belong to different families *Trichoderma viridae, Pseudomonas striata, Pseudomonas fluroscence and Burkholderia cenocepacia* possess different potential in solubilizing zinc. They conduct laboratory experiment using zinc oxide, zinc phosphate and zinc carbonate in media and broath. and found that in plate assay, *Burkholderia cenocepacia* (237.77%) and *Pseudomonas striata* (216.07%) have maximum solubilization efficieny and solubilization index in zinc carbonate media . The highest colony diameter (2.33cm) is formed by *Trichoderma viridae* whereas, *Pseudomonas fluroscence* mainly responsible for declining the pH of zinc carbonate media. In broath assay, maximum solubization is found in *Trichoderma virdae* (458 mg L^{-1}) in zinc carbonate media.

Sunitakumari *et al.,* (2016) isolates 5 strain of zinc solubilizing microbes viz. *Stenotrophomonas maltophilia, Mycobacterium brisbanense, Enterobactor aeroginosa, Pseudomonas aeroginosa* and *Xanthomonas retroflexux* from eight different field of banana, chillie, fieldbean, groundnut, maize, sugarcane, sorghum and tomato found that have high potential in transforming fixed zinc into available form and release phytohormone IAA (Indole Acetic Acid) which promotes plant growth.

Idayu *et al*., (2017) reported the ability of zinc solubilizing bacteria belonging to family of Pseudomonas and Serratia for solubilizing different form of zinc compound in soil. The experimental result show that Pseudomonas dissolve higher amount of zinc carbonate and zinc oxide than zinc phosphate, and also decrease the pH of soil due to the production of gluconic acid by solubilizing the zinc phosphate and zinc oxide as compared to solubilization of zinc carbonate.

Khande and Sharma (2017) reported that effect of zinc solubilizing bacteria on growth and yield of wheat and soybean. They found zinc solubilizing bacteria *Bacillus ceres, Bacillus anthracis, Bacillus thuringiensis, B.tequilensis* and *Bacillus subtilis* produced organic acid like synerginic acid, ferulic acid and caffic acid etc which solubilize complex form of zinc by lowering the soil pH and enhance the supply of zinc in soil.

Othman *et al.,* (2018) reported that inoculation of zinc solubilizing bacteria *Acetobactor sp*. and *Serratia sp*. colonize the rootzone of rice and dissolve the organic form of zinc into inorganic form, thus increase the availability of zinc compound in soil due to which increased root growth and root development at higher rates which enhance the plant to grow vigourously.

Yaghoubi and Khanghahi (2018) reported optimum condition for solubilization of zinc by zinc solubilizing microbes (*Agrobacterium tumefaciens* and *Rhizobium sp*.). These two zinc solubilizing bacteria solubilize insoluble form of zinc into available form by acidification, siderophores production etc. They found that maximum zinc solubilization at pH 8-10 and recorded highest zinc solubilization value 51.4 mg L^{-1} and 72.1 mg L^{-1} by *Agrobacterium tumefaciens* and *Rhizobium sp*

Ebrahim *et al.,* (2019) reported *Pseudomonas japonica* have high potential in promoting plant growth by solubilizing insoluble form of zinc into available form in presence of microorganism. Thus, increase the availability of zinc in soil due to the production of siderophores which is directly proportional to the level of zinc . However, plant height, fresh weight and dry weight of corn increases and ultimately contributing to the higher yield.

Costerousse *et al.,* (2018) reported that strain of *Curtobacterium, Plantibactor, Pseudomonas,* one is *Stenotrophomonas* and another one is *Streptomyces* for zinc solubilizaion through various mechanism mainly acidification via gluconic acid, oxalic and malonic acid production and other mechanism is siderophore production . These microbes are also responsible for phytoextraction in contaminated region and enhance the nutrient uptake of plant by increasing the availability of zinc in deficient soil. Thus improve the nutrient status of soil which ultimately contribute to higher yield in respect of maximum growth attributes and development of crop.

Nitu *et al.*, (2020) reported many zinc solubilizing bacteria like Pseudomonas, Bacillus, Acetobacter, Gluconacebacter, Thiobacillus and Rhizobium play very significant role in improving the soil status by enriching nutrient content. These microbes solubilize complex form of zinc by producing organic acid, and enhance growth and development of plant ultimately increase yield.

Mitra *et al.,* (2020) reported that zinc solubilizing bacteria (*Rhizobium* sp., *Pseudomonas sp., Bacillus sp., Azotobacter sp*.), zinc solubilizing fungi *(Aspergillus sp.*) and actinomycetes (*Streptomyces sp* and *Nocardia sp.*) from different rootzone of soil. They found that these zinc solubilizing bacteria dissolve zinc in more quantity and rapidly. Bacillus sp. R10A, Bacillus sp. R19E and *Pseudomonas sp*. KB9 dissolve 6.124, 6.127 and 6.220 Zn mg l^{-1} and make available in soluble form which is utilized by plant for proper growth and development.

2.2.5 Economics

Sable *et al.*, (2015) reported that efficiency of zinc solubilizing microbes viz. *Burkholderia cepacia, Burkholderia cenocepacia, Pseudosomonas fluorescenes, Pseudomonas straiata, Trichoderma harzianum* and *Bacillus megaterium* along with recommended dose of fertilizers on growth and yield of groundnut. Inoculation of Rhizobium + Pseudomonas + RDF significantly increase dry pod yield and haulm yield of groundnut. Besides these, microbes also recorded highest benefit cost ratio by overcoming the problem of soil fertility and low nutrient use efficiency through integrated nutrient management.

Nagaraju *et al.*, (2017) reported zinc solubilizing bacteria directly or indirectly maximize the productivity of crop by enhancing the growth of plant. A large number of bacteria involve in solubilization of zinc compound viz. *Azospirillium*, *Azotobacter, Pseudomonas, Enterobacter, Arthrobactor, Alcaligenes, Klebsiella, Methanobacterium*, *phyllobacterium* and *serratia*. These zinc solubilizing bacteria play very important role in maintaining nutrients status of soil by overcoming nutrient deficiency in soil as an alternative to chemical fertilizers.

CHAPTER – III

MATERIALS AND METHOD

The research work entitled **"Effect of phosphate and zinc solubilizing microbes on profitability and productivity of fieldpea"** was conducted at Instructional Cum Research Farm, IGKV, Raipur during *rabi* season of 2019-20. The details of raising crop regarding to particular soil condition, climatic situation prevailing in particular area, methodology and treatments applied for successful growth and development of crop are studied briefly in this chapter :

3.1 Location of experimental site

The experiment was conducted at Instructional Cum Research Farm, IGKV, Raipur during rabi season of 2019-20. Geographically, Raipur is located near a large plain and situated at 21°.25' N latitude and 81°.62' E longitude. Its height from mean sea level at 298.15 m. Raipur is the capital of Chhattisgarh comes under eastern plateau and hill agroclimatic zones.

3.2 Climate

Raipur climate is tropical wet and dry. The temperature remain moderate throughtout the year. The rainy season starts from June and end on September. Maximum rainfall occured between July-August. Rainfall is mainly depend on South - West monsoon and least depend on North - East monsoon. Average precipitation 1489 mm received mostly during month of June to September. Average wind velocity is 8 km hr in the month of June. Summer season begin in March and ended in June. May is the hottest month of summer season with an average high temperature of 42.8°C due to Mahanadi basin hot dry storm known as "*loo*". Winter begin from November to February and coolest month is January with average minimum temperature of 21°C.

Climate is the most dominating factors influencing the suitability of a crop to a particular region. The yield potential of a crop mainly depends on climate. More than 50% of variation in yield of crops is due to climatic differences.

3.3 Weather condition during crop period

Weather play significant role in crop growth stages and responsible for achieving higher yield. The most important climatic factor that influence growth, development and ultimately yield of crop during crops period are temperature, rainfall, evaporation, relative humidity and sunshine hours. The meteorological data was recorded at observatory of the agrometeorlogy department, IGKV, Raipur from November to March 2019 – 2020 are presented in Appendix 1 from sowing to harvesting. Maximum temperature was recorded 29.17°C and minimum temperature was 17.05°C. The crop was sown 11th November, 2019 and harvested manually on 15th March, 2020.

The crop received average rainfall 321.2 mm during entire growth season. The maximum temperature during crop period varied from 21.3°C in 1st week of February to 31.4°C in 3rd week of February while minimum temperature varied from 10.8°C in 2nd week of January to 24.3°C in 1st week of October. Wind velocity ranges from 1.2 to 4.1 kmph. The USWB open pan evaporimeter recorded range of evaporation from 11.9 - 34.4 mm during the entire crop period. The sunshine hours ranges from 3.5 - 9.8 hours.

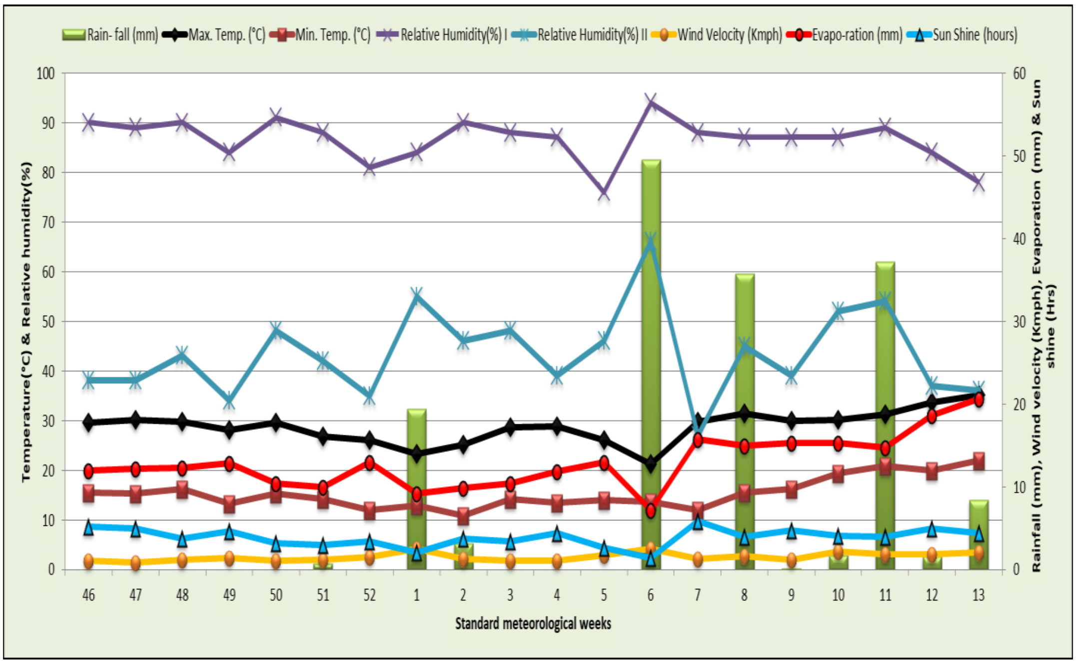


Fig.3.1 Weekly standard meteorological data during crop growth period (from Nov, 2009 to Mar, 2020)

3.4 Physical and chemical properties of soil

To determine the physical and chemical properties of experimental soil (Table 3.1) during entire crop period, randomly soil samples were drawn from depth of 15 cm soil with the help of soil auger before the sowing of crop for the estimation of available nitrogen, phosphorus, potassium and zinc. Soil collected from different spots of field were mixed together. A composite sample was drawn by processing and mixing together and then it is used for soil analysis of different element. The physical and chemical properties of soil in Table **3.1**

Table 3.1 : Physical and chemical properties of soil

Physical Properties	**Analysis Value**	**Class**	**Method uses**
Fine sand (%)	20.42	Vertisols	International pipette method (Black and Evan, 1965)
Silt (%)	35.30	Vertisols	International pipette method
Clay (%)	99.10	Vertisols	Soil core method
Available N (kg ha^{-1})	182.42	Low	Alkaline permagnate method (Subbhiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	8.01	Medium	Olsen's method (Olsen *et al*., 1954)
Available K_2O (Kg ha^{-1})	245.24	High	Flame photometric method (Jackson, 1967)
Available Zn (mg kg^{-1})	0.7	Medium	DTPA method (Lindsay and Norvell, 1956)

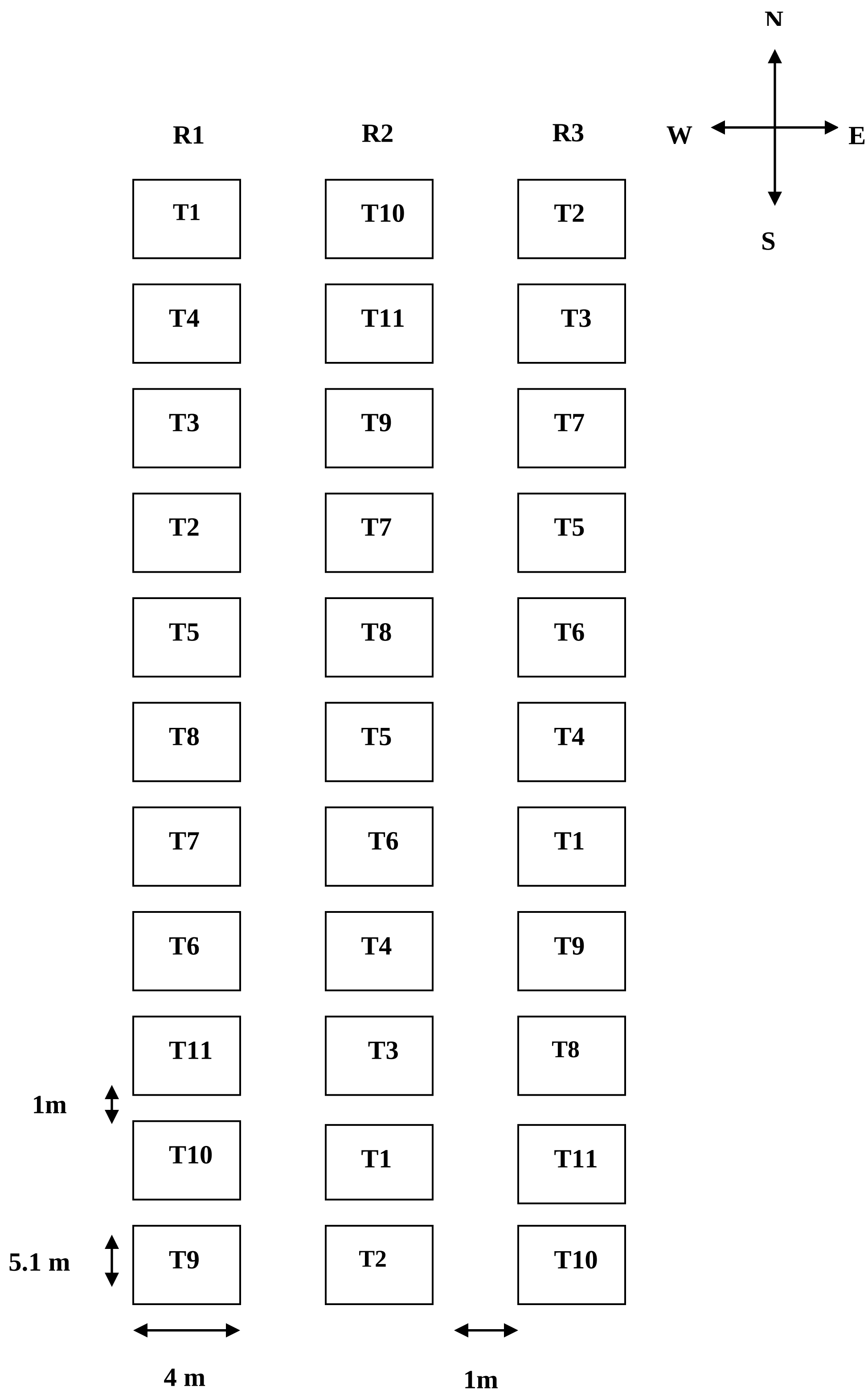


Fig. 3.2. Layout plan of the experiment

3.5 Cropping history of experimental field

Cropping history of preceding crop which are grown in same experimental field given in **Table 3.2**

Table 3.2 Cropping history of experimental field

Year	**Crops**	
	Kharif	**Rabi**
2015- 16	Rice	Lentil
2016 -17	Rice	Lathyrus
2017-18	Rice	Fieldpea
2018-19	Rice	Lathyrus
2019-20	Rice	Fieldpea

3.6 Cultural schedules

S.N	**Cultural operation**	**Method used/Instrument**		**Date**
1.	Soil sampling	Soil auger		11-11-2019
2.	Layout preparation	Manual		11-11-2019
3.	Fertilizers application and sowing	Manual		11-11-2019
4.	Weeding	Manual	1st	01-12-2019
			2nd	20-12-2019
5	Herbicidal spray	Manual		12-11-2019
6.	Harvesting	Manual		15-03-2020
7.	Bundle weight	Manual		19-03-2020
8.	Threshing and winnowing	Manual		19-03-2020

3.7 Experimental Details

Season	:	Rabi, 2019 - 20
Design	:	Randomized Block Design (RBD)

Replication	:	3
Treatment	:	11
Gross plot size	:	5.1.m X 4.0 m (20.4 m^{-2})
Net plot size	:	4.5 m X 3.0 m (13.5 m^{-2})
Crop	:	Fieldpea
Variety	:	Indira Matar-1
Seed rate	:	80 kg ha^{-1}
Spacing	:	30 cm row to row and 10 cm plant to plant

3.8 Treatment details

The experiment was conducted in randomized block design with three replication. The experiment consist of 11 different treatments.

Treatment No	Details
1.	Absolute Control (Without P)
2.	Recommended phosphorous dose application (RDP @ 50 kg ha^{-1})
3.	Soil application of 25 kg $ZnSO_4$ ha^{-1}
4.	Application of Biophos @ 5ml kg^{-1} seed
5.	Application of Biozinc @ 5ml kg^{-1} seed
6.	Application of Biophos + Biozinc @ 5ml kg^{-1} seed
7.	50 % Recommended phosphorous dose application + Biophos @ 5ml kg^{-1} seed
8.	12.5 kg $ZnSO_4$ + Biozinc @ 5ml kg^{-1} seed
9.	50 % Recommended phosphorus dose application + Biophos + Biozinc @ 5ml kg^{-1} seed
10.	50 % Recommended phosphorus dose application + 12.5 kg $ZnSO_4$ + Biophos + Biozinc @ 5ml kg^{-1} seed
11.	Recommended phosphorus dose application + nutrient mobilizer (LNm 43a)

3.9 Test crop

Test crop was fieldpea and variety taken was Indira Matar -1. It was sown as rabi crop and having good branching ability, yield potential and purple coloured flower.

3.10 Sowing and Spacing

80 Kg ha^{-1} seed was sowned manually with a spacing of 30 cm X 10 cm row to row and plant to plant in the depth of 4-5 cm in soil for proper nitrogen fixation. Sowing was done on 11-11-2019.

3.11 Nutrient Mangement

Recommended dose of nitrogen, potassium and sulphur @ 20 kg ha^{-1} respectively, applied as basal dose and seed was treated with 5 gm rhizobium culture kg^{-1} seed at the time of sowing common to all treatment.

3.12 Harvesting

Harvesting was done on 15-03-2020. After 105 -110 days, when about 70-80% pods turn brownish yellow then harvesting was done manually by uprooting the plant. After harvesting, harvested produce was tied in a bundle with the help of rope and allowed for 3-4 days for sun drying

3.13 Threshing and winnowing

Threshing was done by beating the crop with the help of wooden sticks and separated the pod and dry matter with the help of wind fan. Threshed produce have been collected separately as plotwise without contamination.

3.14 Observations

Several observation was taken from each plot randomly during entire growth period of fieldpea. Observed plants were tagged properly for further days. Observation was recorded at 30, 60, 90 DAS and at harvesting of crop. The following observation were taken on growth and yield attributes of fieldpea are as below :

3.14.1 Crop Studies

3.14.1.1 Plant population

Five place randomly selected from each plot for counting the plant population $meter^{-2}$ with the help of quadrates and counted the each plant which are in inside the quadrate. Mean value was taken by recording the plant population value. The observation were taken at initial and before the harvesting of crop plant.

3.14.1.2 Plant height

Randomly five plant were selected for measuring height (cm) and then tagging was done in measured plant for further analysis. For measuring plant height, meter scale was used and measured from base of the plant to the top of the plant. Height was recorded from selected plant of each plot and average height were taken as average height of the plot. The observation of height were taken at 30, 60, 90 DAS and at harvest

3.14.1.3 Number of branches plant^{-1}

Randomly five plant were selected for counting the number of branches plant^{-1} and taken as average number of branches plant^{-1} by dividing the summation of five plant from each plot. The number of branches plant^{-1} was recorded at 30 and 60 DAS.

3.14.1.4 Number of leaves plant^{-1}

Randomly five plant were selected for counting the number of leaves plant^{1} and average number of leaves plant^{-1} are taken by dividing the summation of five plant from each plot. The observation of no of leaves plant^{-1} was recorded at 30 and 60 DAS.

3.14.1.5 Number of nodules plant-^{1}

Randomly five plant were selected for counting the number of nodules plant^{1}. The selected plant sample was uprooted carefully and wash with water for removing the soil mass adhered in roots and counted the pink coloured nodules. Mean value was recorded by dividing the summation of five plant nodules from each plot. The observation of no of nodules plant^{-1} was recorded at 30 and 60 DAS.

3.14.2 Computation

3.14.2.1 Leaf area plant^{-1}

Randomly five plant were selected for measuring leaf area plant^{-1} from each plot with the help of leaf area meter**.** Mean value was taken by recording the plant leaf area plant^{-1}

3.14.2.2 Leaf area index

It is the ratio between leaf area and ground area. Its estimation indicates both assimilation area and growth area.Randomly five plant were selected for obtaining the leaf area plant^{-1} with the help of leaf area meter from each plot. The observation of leaf area index was recorded at 60 and 90 DAS.

$$LAI = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}}$$

3.14.2.3 Leaf Area Duration

It is a measure of the ability of the plant to produce and maintain leaf area.

It is obtained by integrating the LAI over crop growth period and expressed in weeks or days

$$LAD = LAI \times M$$

Where, M = No of days in crop growth period

3.14.2.4 Dry matter accumulation

Five plant was randomly selected from each plot were uprooted carefully along with the root and then remove the root from shoot portion of the plant followed by the sun drying until plant become moisture less. After sun drying, plant sample was taken for hot air drying in hot air oven at 60° C for 48 hours until complete drying of leaves and constant weight was recorded. After that, the air dried plant sample was taken for measuring weight by using electric balance. The average weight was recorded by dividing the summation by five plant sample.

3.14.2.5 Crop growth rate (CGR)

It is the rate of growth of crop per unit area and expressed as g/m^2/day. The dry weight of a plant taken at different time interval was calculated. The observation was recorded at 0-30, 30-60, 60-90 and 90- at harvest.

$$CGR(g/m^2/day) = \frac{W_2 - W_1}{T_2 - T_1}$$

Where, W_1 and W_2 are dry weight of plant at time T_1 and T_2, respectively

3.14.2.6 Relative growth rate (RGR)

The increase in dry weight in unit time over the original weight of the plant. It is expressed in g/g/day. The observation was recorded at 0-30, 30-60, 60-90 and 90- at harvest.

This formula is given by Lepold and Kriedman (1975) :

$$RGR\ (g/g/day) = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1}$$

Where W_1 and W_2 are the dry weight of the plant

T_1 and T_2 are the time

3.14.2 Yield attributes and yield studies

3.14.3.1 No of pod plant^{-1}

Randomly five plant were selected for counting the number of pods plant^{-1} Mean value was recorded by dividing the summation of five plant pods from each plot.

3.14.3.2 No. of seeds pod^{-1}

For counting the total number of seed pod^{-1} from total no of pod selected from randomly selected plant. Average value was worked out for further statistical analysis

3.14.3.3 100 seed weight (Seed index)

Healthy seed sample from each net plot was taken for measuring seed weight. Before measuring the weight of 100 seed sample and this 100 seed sample were oven dry till constant weight was obtained. Then by using electric balance, seed index were taken preciously.

3.14.3.4 Seed yield (kg ha^{-1})

After harvesting, seed yield was recorded from each net plot by measuring the weight of seed with the help of weighing machine accurately in kg and then convereted into qn. Seed yield of each plot was recorded separately.

3.14.3.5 Stover yield (kg ha^{-1})

After threshing, Stover yield was recorded by removing the seed and dry matter, then recorded the stover yield by using spring balance in kg.

3.14.3.6 Harvest Index (kg ha^{-1})

The efficient assimilation of CO_2 in the form of photosynthesis is expressed in terms of harvest index or coefficient of effectiveness.

The total dry matter produced by a crop is known as biological yield and the fraction of biological yield which is useful for man is known as economic yield

$$\text{Harvest Index} = \frac{\text{Economic yield (grain)}}{\text{Biological yield (grain + strover)}} \times 100$$

3.14.4 Chemical study

3.14.4.1 Nutrient status of soil

Soil sampling was done just before the sowing of crop and after the harvesting of crop. For available N in soil was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956), for available phosphorus by olsen's method (Olsen, 1954), for potassium by neutral normal ammonium acetate and for zinc estimation DTPA (Di-ethylene-tri-amine-penta acetic acid) method was used (Lindsey and Novell, 1978)

3.14.4.2 Nutrient status of plant

Plant sampling was done for estimation of P and Zn. Plant sample was dry at 60 °C in oven until the constant weight was obtained. Estimation of Nitrogen, Kjeldalh method, for phosphorus, Vandemolybdate phosphoric acid yellow colour, for potassium , flame photometer was used and for zinc, DTPA (Di-ethylene-tri-amine-penta acetic acid) method was used

3.14.4.3 Nutrient uptake

Nutrients content in grain and straw was calculated by their respective yield of dry matter to achieve total uptake of nutrients (kg ha^{-1}) by plants.

Nutrient uptake of grain and straw was calculated by formula:

$$\text{Nutrient uptake (Kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)} \times \text{Dry matter (kg ha}^{-1}\text{)}}{100}$$

3.14.4.4 Protein content and protein yield

Kjeldalh method was used for estimating nitrogen content in fieldpea seed and calculated protein percent by multiplying nitrogen content by the factor of 6.25

3.14.5 Economics

3.14.5.1 Cost of cultivation

Cost of cultivation is the total expenditure incurred for raising crops in a cropping system. It was obtained by including all cost required for the raising of crop from cost of land value of seed, manures to the harvesting and storage of crops.

3.14.5.2 Gross Return

It was calculated based on the local market prices. Total monetary value of economic produce and by product obtained from the crop is gross returns.

Gross return (Rs ha^{-1}) = Grain yield + stover yield
(Rs ha^{-1}) (Rs ha^{-1})

3.14.5.3 Net returns

Net returns was obtained by substracting cost of cultivation from gross returns. This represents the actual income of farmers.

Net returns (Rs ha^{-1}) = Gross returns - cost of cultivation
(Rs ha^{-1}) (Rs ha^{-1})

3.11.5.4 Benefit : cost ratio

It is the ratio of gross returns to cost of cultivation.

$$B:C = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

3.12 Statistical analysis

The experiment was laid out in randomized block design. The data were analysis as per the standard procedure defined by Gomez and Gomez (1954) for "Analysis of variance" (ANOVA). ANOVA table was prepared in the following way for each character and given in Table 3.12

Table 3.12 Skeleton of ANOVA

Sources of Variation	Degree of freedom	Sum of square	Mean sum of square	F calculated value
Replication	(r-1)	RSS	RSS/(r-1) = RMS	RMS/EMS
Treatment	(t-1)	TrSS	TrSS/(t-1) = TMS	TMS/EMS
Error	(r-1) (t-1)	ESS	ESS/(r-1)(t-1) =EMS	
Total	rt-1			

To test the significance of treatment, the calculated value of F was compared with table value of F at 5% level of probability against error degree of freedom.

$$\textbf{SEm}\pm = \sqrt{EMS/r}$$

$$\textbf{CD} = \sqrt{(2EMS/r)} \ \textbf{X t}_{\text{error d.f at 5\%}}$$

CV(%) = $\sqrt{EMS/GM}$ **X 100**

Where,

R = Number of replication

T = Number of treatment

CD. = Critical difference

MSS. = Mean sum of square

RMS = Replication sum of square

SEm ± = Standard error of mean

d.f = Degree of freedom,

S.S. = Sum of square,

CV. = Coefficient of variance,

EMS = Error mean square

TMS = Treatment sum of square

GM = General mean

CHAPTER – IV
RESULT AND DISCUSSION

The research work entitled **"Effect of phosphate and zinc solubilizing microbes on profitability and productivity of fieldpea"** was conducted at Instructional Cum Research Farm, IGKV, Raipur during *rabi* season of 2019-20. The experiment was conducted to know the effect of phosphate and zinc solubilizing microbes on growth attributes and yield attributes of fieldpea. The result observed on different growth parameter which was further contributed on production and productivity of fieldpea. In this chapter, various parameters are recorded on the basis of observation taken at different interval of crop period under different treatments. The result obtained in respect of various crop growth and yield attributes are presented and interpreted with the help of table and graphic are in following heads;

4.1 Crop studies

4.1.1 Plant population (No m^{-2})

Plant population data are presented in Table 4.1. The data indicate that effect of phosphate and zinc solubilzing microbes on plant population of fieldpea. The observation was recorded at 30 DAS and at harvest. The result revealed that the plant population value ranges from 34 to 38 at initial and at harvest ranges from 34 to 37 under different treatments. The result showed that plant population at 30 DAS and at harvest was remain unaffected due to phosphate and zinc solubilizing microbes. Similarly, maximum plant population was (38) recorded at 30 DAS under 4 different treatments *i.e* T_2 : RDP @ 50 kg ha^{-1}, T_4 : Application of Biophos, T_9 : 50% RDP + Biophos + Biozinc and T_{11} : RDP + nutrient mobilizer (LNm 43a). Therefore, all the treatments showed non-significant impact on plant population of fieldpea. Yield of crop is the result of final plant population which depends on seed germination rate and survival rates. Establishment of optimum plant population is essential to get maximum yield. Optimum plant population depend on size of plant, elasticity, foraging area and nature of plant etc.

Table 4.1 Effect of phosphate and zinc solubilzing microbes on plant population (m^{-2}) of fieldpea at different interval of time

Treatments	Plant population (m^{-2})	
	30 DAS	At harvest
Absolute control (without P)	36	34
RDP application (@ 50 kg ha^{-1})	38	36
Soil application of 25 kg $ZnSO_4$ ha^{-1}	37	34
Application of Biophos	38	37
Application of Biozinc	37	36
Application of Biophos + Biozinc	35	33
50% RDP + Biophos	34	31
12.5 kg $ZnSO_4$ + Biozinc	34	32
50% RDP + Biophos + Biozinc	38	37
50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc	36	34
RDP + nutrient mobilizer (LNm 43a)	38	36
SEm±	1.2	1.4
CD at 5%	NS	NS

4.1.2 Plant height

Plant height data are presented in Table 4.2. The table indicated the synergistic effect of phosphate and zinc solubilizing microbes on plant height of fieldpea. Plant height is plant size as a indicator of growth. The observation of plant height was recorded at 30, 60, 90 DAS and at harvest. The result revealed that plant height was minimum upto 30 DAS but it was increased during 60 and 90 DAS due to increase in the age of crop. The plant height value ranges from 35.8 to 50.7 at 60 DAS and 42.3 to 63.1 at 90 DAS under different treatment. Significantly, maximum plant height value was 50.7 recorded at 60 DAS and 63.1 at 90 DAS under T_{11} : RDP + nutrient mobilizer (LNm43a) and found superior among the treatments. It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (47.8 cm at 60 DAS and 60.2 cm at 90 DAS), T_9 : 50% RDP + Biophos + Biozinc (47.2 cm at 60 DAS and 59.4 cm at 90 DAS), T_2 : RDP application (@ 50 kg ha^{-1}) (46.5 at 60 DAS) and T_7 : 50% RDP + Biophos (15.8 at 30 DAS). While, minimum plant height value was 35.8 recorded at 60 DAS and 42.3 at 90 DAS under T_1 : control plot. The result showed that due to synergistic effect of phosphate and zinc solubilizing microbes, there was significant variation in plant population at 30, 60 90 DAS and at harvest was observed.

Ganie *et al*., (2009) reported that effect of inoculation of biofertilizers like PSB, Rhizobium and Acetobactor gave superior result on promoting highest plant height (45.26 cm) in gardenpea. Kuhawat *et al.*, (2009) also found that combined application of organic manures, inoculation of phosphorus solubilizing bacteria (*Bacillus polymyxra*) and phosphorus fertilization were helpful in recording highest plant height. Kant *et al*., (2016) recorded highest plant height in urdbean under 75% kg ha^{-1} P_2O_5 + PSB + Rhizobium treatments.

Table 4.2 Effect of phosphate and zinc solubilzing microbes on plant height of Fieldpea at different interval of time

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
Absolute Control (Without P)	11.7	35.8	42.3	44.4
RDP application (@ 50 kg ha^{-1})	16.5	46.5	57.4	59.6
Soil application of 25 kg $ZnSO_4$ ha^{-1}	14.4	43.9	46.6	48.9
Application of Biophos	14.6	41.1	48.6	51.0
Application of Biozinc	15.1	41.4	51.7	54.2
Application of Biophos + Biozinc	14.9	45.2	53.5	56.1
50 % RDP + Biophos	15.8	45.7	55.6	58.3
12.5 kg $ZnSO_4$+ Biozinc	14.6	43.3	57.3	60.1
50 % RDP + Biophos + Biozinc	16.6	47.2	59.4	62.3
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	16.9	47.8	60.2	63.2
RDP + nutrient mobilizer (LNm 43a)	17.0	50.7	63.1	67.2
SEm ±	0.5	1.5	1.9	2.0
CD at 5%	1.5	4.5	5.5	5.8

4.1.3 Number of branches $plant^{-1}$

The data pertaining to number of branches are presented in Table 4.3. The observation of number of branches plant^{-1} was recorded at 30 and 60 DAS and found that number of branches plant^{-1} significantly influenced at all the growth stage of fieldpea except 30 DAS due to phosphate and zinc solubilizing microbes. The result revealed that number of branches plant^{-1} value ranges from 2.18 to 3.12 recorded at 60 DAS under different treatment. Due to the positive interaction between microorganism gave superior result on promoting number of branches plant^{-1}. Significantly, maximum numbers of branches was (3.12) recorded at 60 DAS under T_{11} : RDP + nutrient mobilizer (LNm43a) treatment as compared to other treatments. It was at par T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (2.96 at 60 DAS) and T_9 : 50% RDP + Biophos + Biozinc (2.92 at 60 . While, minimum number of branches plant^{-1} value was (2.18) recorded at 60 DAS under T_1 : control plot. The result showed that due to presence of phosphate and zinc solubilizing microbes, there was significant variation on number of branches plant^{-1} at 60 DAS

Ramana *et al.*, (2010) recorded maximum number of branches by co-inoculation of VAM @ 2 kg ha^{-1} + PSB @ 2.5 kg ha^{-1} + 75% RDF. Rather *et al.*, (2010) found that inoculation of Rhizobium, Acetobactor and PSB in fieldpea gave beneficial result on promoting highest number of branches plant^{-1} (4.20). Kalayu *et al.*, (2019) also recorded maximum number of branches due to inoculation of phosphorus solubilizing microorganism belong to genus Bacillus and Pseudomonas.

4.1.4 Number of leaves plant^{-1}

Data on leaf area plant^{-1} was recorded in Table 4.4 which was recorded at 30 and 60 DAS. The result show that phosphate and zinc solubilizing microbes significantly increases number of leaves plant^{-1} at all the stage of growth except at 30 DAS and found to be non- significant variation. Solar radiaton, temperature, mineral nutrients and water status are important factor that decide the number of leaves and size of leaf. Leaf expansion is normal if the relative water content is 90-100%. The result revealed that the number of leaves plant^{-1} value ranges from 71.4 to 84.6 was recorded at 60 DAS under different treatment. Significantly, maximum numbers of leaves plant^{-1} value was 84.6 recorded at 60 DAS under T_{11} : RDP +

nutrient mobilizer (LNm43a) treatment. It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (82.8), T_9 : 50% RDP + Biophos + Biozinc (82.4), T_2 : RDP application (@ 50 kg ha^{-1} (80.6), T_7 : 50 % RDP + Biophos (79.6) and T_6 : Application of Biophos + Biozinc (78.2). While, minimum number of leaves $plant^{-1}$ value was 71.4 recorded under T_1 : control plot. The result also showed that due to phosphate and zinc solubilizing microbes, there was significant variation in number of leaves $plant^{-1}$ at 60 DAS.

Ganie *et al*., (2009) also found that inoculation of Rhizobium, Acetobactor and PSB in fieldpea gave beneficial result on producing maximum number of leaves $plant^{-1}$ (13.33). Rather *et al*., (2019) also conducted the same experiment and found that maximum number of leaves $plant^{-1}$ (13.33) due to inoculation of biofertilizers. Kalayu *et al*., (2019) also recorded maximum number of leaves due to inoculation of phosphorus solubilizing microorganism belong to genus Bacillus and Pseudomonas.

Table 4.3 Effect of phosphate and zinc solubilzing microbes on number of branches $plant^{-1}$ of fieldpea at different time intervals

Treatments	No of branches $plant^{-1}$ 30 DAS	No of branches $plant^{-1}$ 60DAS
Absolute control (Without P)	1.62	2.18
RDP application (@ 50 kg ha^{-1}	1.66	2.82
Soil application of 25 kg $ZnSO_4$ ha^{-1}	1.70	2.23
Application of Biophos	1.68	2.35
Application of Biozinc	1.64	2.24
Application of Biophos + Biozinc	1.67	2.35
50 % RDP + Biophos	1.53	2.30
12.5 kg $ZnSO_4$+ Biozinc	1.66	2.34
50 % RDP + Biophos + Biozinc	1.56	2.92
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	1.58	2.96
RDP + nutrient mobilizer (LNm 43a)	1.72	3.12
SEm±	0.54	0.08
CD at 5%	NS	0.26

Table 4.4 Effect of phosphate and zinc solubilzing microbes on number of Leaves plant^{-1} of fieldpea at different time intervals

Treatment	No of leaves plant^{-1}	
	30 DAS	60DAS
Absolute Control (Without P)	28.6	71.4
RDP application (@ 50 kg ha^{-1})	32.4	80.6
Soil application of 25 kg $ZnSO_4$ ha^{-1}	29.8	73.6
Application of Biophos	31.8	73.0
Application of Biozinc	30.5	73.2
Application of Biophos + Biozinc	32.6	78.2
50 % RDP + Biophos	32.8	79.6
12.5 kg $ZnSO_4$+ Biozinc	31.2	75.2
50 % RDP + Biophos + Biozinc	32.7	82.4
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	33.6	82.8
RDP + nutrient mobilizer (LNm 43a)	33.9	84.6
SEm±	1.09	2.6
CD at 5%	NS	7.8

4.1.5 Numbers of nodules plant^{-1}

Data presented in Table 4.5 revealed that effect of inoculation of phosphate and zinc solubilizing microbes on numbers of nodules plant^{-1} of fieldpea. The result showed that non - significant impact was found regarding numbers of nodules plant^{-1} in fieldpea at 30 and 60 DAS. Bacterial nodules are mostly found on secondary roots in all legumes. It was observed that maximum number of nodules increases upto 60 DAS. After this, nodulation start declining .The result revealed that the numbers of nodules ranges from 6.9 to 7.0 at 30 DAS and 9.4 to 10.2 at 60 DAS under different treatment. Among the treatment, numbers of nodules plant^{-1} almost remain the same due to phosphate and zinc solubilizing microbes in fieldpea.

Table 4.5 Effect of phosphate and zinc solubilzing microbes on number of nodules plant^{-1} at different intervals

Treatments	No of nodules plant^{-1}	
	30 DAS	60 DAS
Absolute control (Without P)	6.9	9.4
RDP application @ 50 kg ha^{-1}	6.8	9.8
Soil application of 25 kg $ZnSO_4$ ha^{-1}	6.4	9.9
Application of Biophos	6.7	9.2
Application of Biozinc	6.6	9.4
Application of Biophos + Biozinc	6.4	9.7
50 % RDP + Biophos	6.7	9.9
12.5 kg $ZnSO_4$+ Biozinc	6.4	10.4
50 % RDP + Biophos + Biozinc	7.0	10.0
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	7.1	10.5
RDP + nutrient mobilizer (LNm 43a)	7.0	10.2
SEm±	0.2	0.34
CD at 5%	NS	NS

4.2 Computation

4.2.1 Leaf Area plant^{-1}

The data presented on leaf area plant^{-1} Table 4.6 indicates significant increase in effect of phosphate and zinc solubilizing microbes on leaf area plant^{-1} of fieldpea. The observation was recorded at 30, 60 and 90 DAS. The result also showed that due to phosphate and zinc solubilizing microbes, there was non - significant variation in leaf area plant^{-1} at 30 and significant variation in leaf area plant^{-1} at 60 and 90 DAS. Among the treatment, maximum leaf area plant^{-1} was 95.5 to 138.5 at 60 DAS and 125.8 to 156.8 at 90 DAS. The result indicate that maximum leaf area plant^{-1} was (138.5) at 60 DAS and (156.8) at 90 DAS under T_{11} : RDP + nutrient mobilizer (LNm43a). It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (133.8 at 60 DAS and 151.8 at 90 DAS), T_9 : 50% RDP + Biophos + Biozinc (128.5 at 60 DAS and 146.2 at 90 DAS), T_2 : RDP application (@ 50 kg ha^{-1}) (143.4 at 90 DAS) and T_7 : 50 % RDP + Biophos (143.2 at 90 DAS). While, the minimum leaf area plant^{-1} was 95.5 at 60 DAS and 125.8 at 90 DAS observed under T_1 : control plot.

Table 4.6 Effect of phosphate and zinc solubilzing microbes on leaf area plant (cm^2) of fieldpea at different time interval

Treatments	Leaf area plant (cm^2)		
	30 DAS	60 DAS	90 DAS
Absolute Control (Without P)	33.5	95.5	125.8
RDP application (@ 50 kg ha^{-1}	38.2	120.3	143.4
Soil application. of 25 kg $ZnSO_4$ ha^{-1}	34.7	102.3	133.9
Application of Biophos	37.5	106.0	139.2
Application of Biozinc	36.7	103.3	136.2
Application of Biophos + Biozinc	38.0	118.6	140.4
50 % RDP + Biophos	38.3	118.7	143.2
12.5 kg $ZnSO_4$+ Biozinc	37.6	118.5	140.2
50 % RDP + Biophos + Biozinc	38.6	128.5	146.2
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	39.1	133.8	151.8
RDP + nutrient mobilizer (LNm 43a)	40.4	138.5	156.8
SEm ±	1.3	4.1	4.9
CD at 5%	NS	12.1	14.4

4.2.2 Leaf Area Index

The data presented in Table 4.7 indicates significant effect of phosphate and zinc solubilizing microbes on leaf area index of fieldpea except at 30 DAS .The observation was recorded at 30, 60 and 90 DAS. The result show that maximum leaf area index was observed at 60 DAS. Leaf area index is the most important factors influencing growth. Leaf area decides the amount of solar radiation intercepted. Leaf area index slowly in the early stages of crop growth and rapidly after later stage. LAI for maximum dry matter production which is reached when the largest number of leaves receive just sufficient light for photosynthesis to balance respiration. With the increase in leaf area index, light interception also increases. As the solar radiation enter the crop canopy, it quantity is gradually decreased by the crops. Maximum leaf area index was 1.43 and 1.63 at 60 and 90 DAS under T_1 : RDP + nutrient mobilizer (LNm43a). It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (1.40 at 60 DAS and 1.58 at 90 DAS) and T_9 : 50% RDP + Biophos + Biozinc (1.34 at 60 DAS and 1.52 at 90 DAS). While, the minimum leaf area index was 0.98 at 60 DAS and 1.13 at 90 DAS observed under T_1 : control plot. The result also showed that due to phosphate and zinc solubilizing microbes, there was non - significant variation in leaf area index at 30 and significant variation in leaf area index at 60 and 90 DAS. Optimum LAI is between 3-4 for crops with horizontally oriented leaves and 6-9 for crops with upright leaves.

Table 4.7 Effect of phosphate and zinc solubilzing microbes on leaf area index of fieldpea at different time interval

Treatments	Leaf Area Index		
	30 DAS	60 DAS	90 DAS
Absolute Control (Without P)	0.610	0.980	1.133
RDP application (@ 50 kg ha^{-1})	0.683	1.237	1.413
Soil application of 25 kg $ZnSO_4$ ha^{-1}	0.640	1.050	1.210
Application of Biophos	0.650	1.097	1.260
Application of Biozinc	0.677	1.067	1.227
Application of Biophos + Biozinc	0.680	1.230	1.397
50 % RDP + Biophos	0.667	1.250	1.420
12.5 kg $ZnSO_4$+ Biozinc	0.673	1.227	1.390
50 % RDP + Biophos + Biozinc	0.687	1.343	1.520
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	0.690	1.400	1.580
RDP + nutrient mobilizer (LNm 43a)	0.700	1.433	1.633
SEm±	0.022	0.042	0.048
CD at 5%	NS	0.124	0.143

4.2.3 Leaf area duration

The data of leaf area duration was presented in Table 4.8 which was observed at 30 DAS and 60 DAS. The table revealed that use of phosphate and zinc solubilizing microbes show positive response towards leaf area duration in fieldpea at 60 DAS. The leaf area duration was examined at all the growth stages and it measure the ability of plant to maintain and produce leaf area. The maximum leaf area duration was 1.43 observed at 60 DAS found under T_{11} : RDP + nutrient mobilizer (LNm43a). It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (1.40 at 60 DAS) and T_9 : 50% RDP + Biophos + Biozinc (1.34 at 60 DAS). While, minimum leaf area duration was 0.98 recorded under T_1 : control plot. The result also showed that due to phosphate and zinc solubilizing microbes, there was non - significant variation in leaf area duration at 30 DAS and significant variation in leaf area duration at 60 DAS.

Table 4.8 Effect of phosphate and zinc solubilzing microbes on leaf area leaf area duration of fieldpea at different time interval

	Leaf Area Duration	
Treatments	**30 DAS**	**60 DAS**
Absolute Control (Without P)	0.610	0.980
RDP application (@ 50 kg ha^{-1})	1.683	1.250
Soil application of 25 kg $ZnSO_4$ ha^{-1}	0.640	1.050
Application of Biophos	0.667	1.067
Application of Biozinc	0.650	1.097
Application of Biophos + Biozinc	0.677	1.237
50 % RDP + Biophos	0.687	1.227
12.5 kg $ZnSO_4$+ Biozinc	0.673	1.343
50 % RDP + Biophos + Biozinc	0.686	1.343
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	0.690	1.400
RDP + nutrient mobilizer (LNm 43a)	0.700	1.433
SEm±	0.022	0.042
CD at 5%	NS	0.124

4.2.4 Dry matter accumulation $plant^{-1}$

The data are presented in Table. 4.9. indicates significant increases in dry matter accumulation $plant^{-1}$ at all the growth stages due to phosphate and zinc solubilizing microbes in fieldpea. The data was recorded at 30, 60, 90 DAS and at harvest. The pre-requisite for high yields was a high production of total dry matter per unit area. The amount of dry matter produced depend on photosynthesis which in turns depends on large and efficient assimilating area, adequate supply of solar radiation, CO_2 and favourable environment condition. Significantly maximum dry matter accumulation $plant^{-1}$ at 30, 60, 90 DAS and harvest was 1.79, 6.90, 10 and 14.07 recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (1.69, 6.77, 9.77 and 13.80), T_9 : 50% RDP + Biophos + Biozinc (1.58, 6.57, 9.47 and 13.37), T_2 : RDP application (@ 50 kg ha^{-1}) (1.73, 6.32, 9.43 and 13.13) and T_7

: 50 % RDP + Biophos (9.17 and 13.05) (at 90 DAS and harvest). While, minimum dry matter accumulation plant^{-1} was (1.49, 4.99, 6.90 and 10.20). recorded under T_1 : control plot

Meena *et al.,* (2015) revealed that inoculation of phosphorus solubilizing microbes significantly increase the dry matter yield plant^{-1}. Oteino *et al.,* (2015) found that phosphorus solubilizing bacteria endophytic *Pseudomonas* producing gluconic acid, helpful in solubilizing insoluble phosphorus and stimulate gowth and yield attributes in terms of dry matter yield plant^{-1}. Tagore *et al.,* (2013) recorded highest dry matter yield plant^{-1} by inoculation of Rhizobium and Phosphorus solubilizing bacteria belong to *Pseudomonas striata, Bacillus megatarium, Bacillus polymyxra.*

Table 4.9 Effect of phosphate and zinc solubilzing microbes on dry matter accumulation plant^{-1} of fieldpea at different time interval

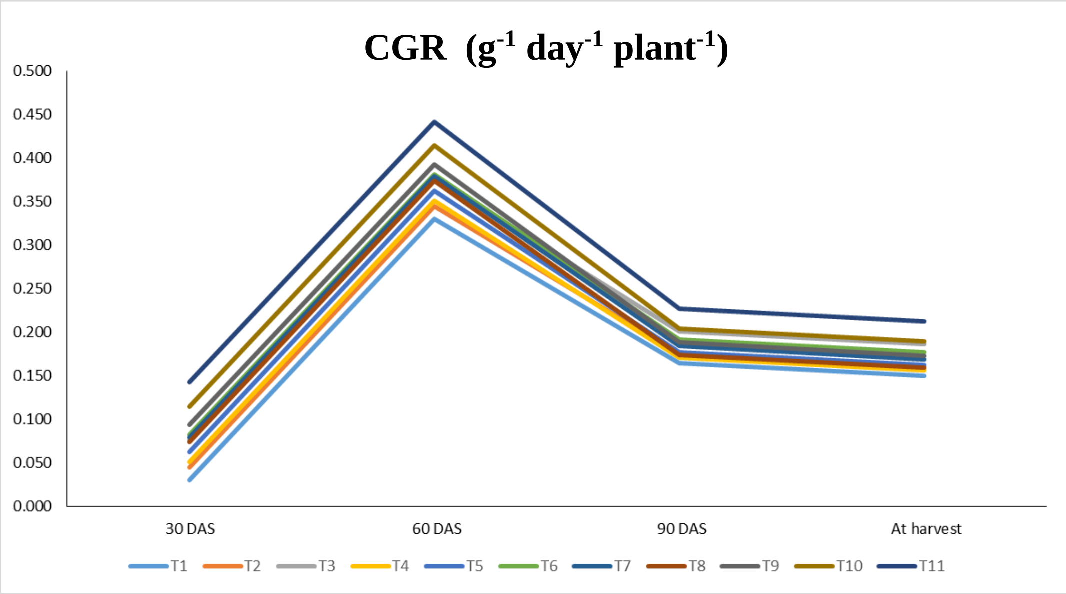
Treatments	Dry matter accumulation plant^{-1}(g)			
	30 DAS	**60 DAS**	**90 DAS**	**at harvest**
Absolute Control (Without P)	1.49	4.99	6.90	10.20
RDP application (@ 50 kgha^{-1})	1.73	6.32	9.43	13.13
Soil application of 25 kg $ZnSO_4$ ha^{-1}	1.49	5.30	7.89	11.02
Application of Biophos	1.50	5.57	8.19	12.55
Application of Biozinc	1.42	5.80	7.89	12.20
Application of Biophos + Biozinc	1.48	5.90	8.67	12.70
50 % RDP + Biophos	1.50	6.17	9.17	13.05
12.5 kg $ZnSO_4$+ Biozinc	1.45	5.97	8.30	12.65
50 % RDP + Biophos + Biozinc	1.58	6.57	9.47	13.37
50 % RDP + 12.5 kg $ZnSO_4$+Biophos + Biozinc	1.69	6.77	9.77	13.80
RDP + nutrient mobilizer (LNm 43a)	1.79	6.90	10.00	14.07
SEm±	0.05	0.20	0.20	0.43
C.D.	0.15	0.61	0.88	1.28

4.2.5 Crop growth rate

The data are presented in Fig. 4.1 indicates significantly increases in crop growth rate due to phosphate and zinc solubilizing microbes in fieldpea. The data was recorded at 30, 60, 90 DAS and at harvest. In general, crop growth increase progressively upto the physiological maturity. But quantum jump was observed during 60-90 days. The result revealed that increase in crop growth rate with advancement in crop growth stages under different treatment. Similarly, maximum crop growth rate at all the stage was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a) due to microbes, crop grows at faster rate, start producing branches and cover the grounds as much as possible, to intercept more radiation as compared to other treatment. Crop growth rate depended on several factors like solar radiation, temperature, soil moisture, soil aeration and mineral nutrients. While, minimum crop growth rate was recorded under T_{11} : control plot. The result also showed that due to phosphate and zinc solubilizing microbes, there was significant variation in crop growth rate of fieldpea.

4.2.6 Relative growth rate

The data are presented in Fig. 4.1 indicates significantly increases in relative growth rate due to phosphate and zinc solubilizing microbes in fieldpea. The data was recorded at 30, 60, 90 harvest and at harvest. Relative growth rate decrease over time, as the biomass increases because of the non-photosynthetic tissue and also due to soil nutrient become less. The result revealed that maximum relative growth rate was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. While, minimum relative growth rate was observed under T_1 : control plot. The result also showed that due to phosphate and zinc solubilizing microbes, there was significant variation in relative growth rate of fieldpea.



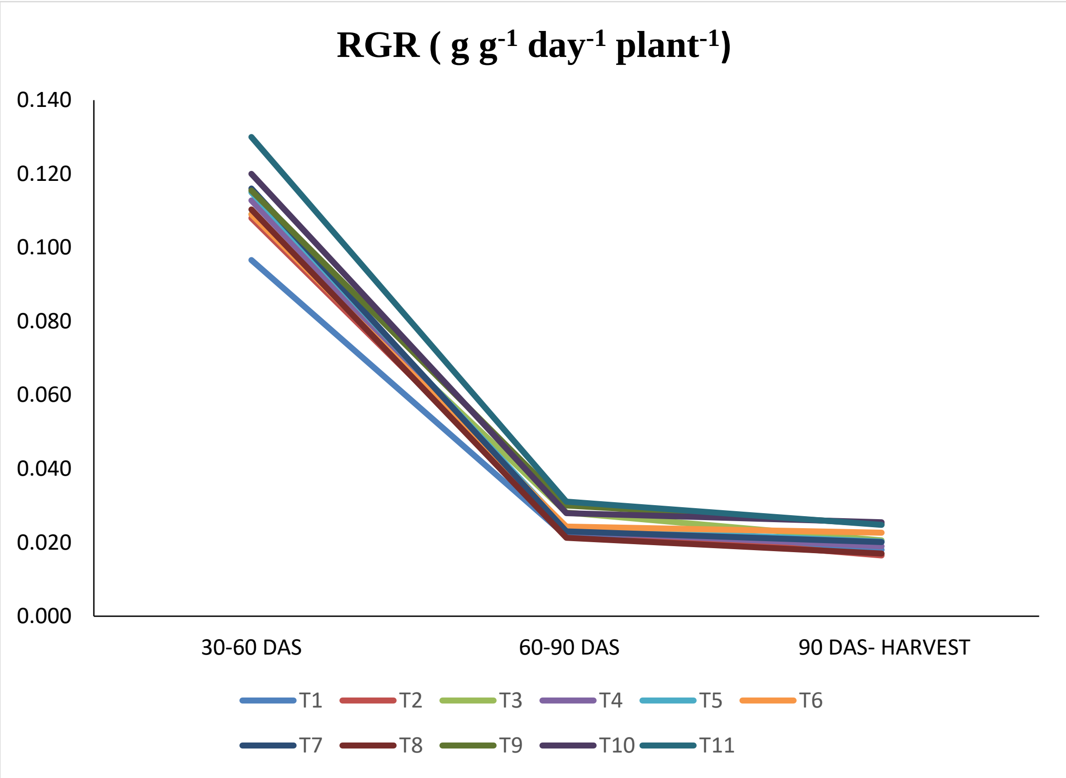


Fig.4.1 CGR and RGR of fieldpea at different time intervals of fieldpea

4.3. Yield attributes and yield

4.3.1 Number of pods plant^{-1}

The data was presented regarding number of pods plant^{-1} in Table 4.10 recorded after the harvesting of crop. The result show that inoculation of phosphate and zinc solubilizing microbes significantly increase the number of pods plant^{-1} in fieldpea. The result indicates the positive effect of phosphate and zinc solubilizing microbes on number of pods plant^{-1} ranges from 10 to 29 among different treatment. The result revealed significantly maximum number of pods plant^{-1} 29 was recorded under T_{11} : RDP + nutrient mobilizer (LNm43a) due to positive effect of nutrients , increase the flower formation and fruit setting. While, minimum numbers of pods was (10) recorded at under T_1 : control plot. During the pod growth stages, higher amount of photosynthase accumulated in the fruits and seeds from leaves and retranslocated from other parts.

It is clear that number of pods plant^{-1} increases due to increase in nutrient content of soil by inoculation of microorganism which have potential to solubilize insoluble form of phosphorus into soluble form and also responsible for releasing phytohormone IAA (62.7-182.1mg^{-ml}) which is directly responsible for growth and yield attributes of fieldpea. This finding was confirmed by Meena *et al.,* (2015) and Oteino *et al.,* (2015) recorded maximum number of pods plant^{-1}. Kant *et al.,* (2005) found that inoculation of phosphate solubilizing microbes *i.e. Pseudomonas fluroscene* along recommended dose phosphorus fertilizer the number of pod m^{-2}. Dey *et al.,* (2004) recorded maximum number of pod in peanut (*Arachis hypogaea* L.) due to inoculation of *Pseudomonas fluroscene*.

4.3.2 Number of seed pod^{-1}

Data presented on Table 4.10 revealed that effect of inoculation of phosphate and zinc solubilizing microbes on numbers of seeds pod^{-1} in fieldpea. The result revealed that numbers of seeds pod^{-1} value ranges from 3.90 to 4.50 under different treatments and found to be no variation among the treatments. However maximum numerical value of number of seed pod^{-1} was (4.50) under T_{11} : RDP + nutrient mobilizer (LNm43a). While, minimum numbers of seed pod^{-1} was 3.90 recorded under T_1 : control plot.

4.3.3 100 seed weight (Seed index)

The data was presented regarding 100 seed weight in Table 4.10.The result indicated that there was no significant impact was observed with regard to seed index. Numerically, being maximum seed index value was (14.93) was observed under T_{11} : RDP + nutrient mobilizer (LNm43a). While, minimum seed index value 14.72 was recorded under T_1 : control plot. Therefore, seed index value remain same, neither heavier nor lighter seed index among the treatments. The result also revealved that due to phosphate and zinc solubilizing microbes, there was non-significant variation on seed index of fieldpea

Table.4.10. Effect of phosphate and zinc solubilzing microbes on number of pods plant^{-1}, seed pod^{-1} and seed index of fieldpea

Treatments	Pods plant^{-1} (no.)	Seed pod^{-1} (no)	Seed wt.
Absolute control (Without P)	10	3.90	14.72
RDP application (@ 50 kg ha^{-1})	25	4.20	14.86
Soil application of 25 kg $ZnSO_4$ ha^{-1}	11	4.00	14.74
Application of Biophos	13	4.10	14.78
Application of Biozinc	12	4.23	14.76
Application of Biophos + Biozinc	17	4.1	14.81
50 % RDP + Biophos	21	4.20	14.84
12.5 kg $ZnSO_4$+ Biozinc	14	4.27	14.79
50 % RDP + Biophos + Biozinc	25	4.30	14.89
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	26	4.40	14.91
RDP + nutrient mobilizer (LNm 43a)	29	4.50	14.93
SEm±	0.66	0.14	5.09
CD at 5%	1.97	NS	NS

4.3.4 Seed yield

Data pertaining to grain yield and presented in presented in Table 4.11. The data revealed that there was significant variation in grain yield among different treatments due to presence of phosphate and zinc solubilizing microbes. Yield is the result of final plant population, number of pods plant^{-1}, no of seeds pod^{-1} and seed index etc. The amount of economic yield depends on the manner in which the net dry matter is produced among different parts of the plant. The data revealed that inoculation of phosphate and zinc solubilizing microbes in fieldpea significantly produce higher grain yield. The result revealed that value of grain yield ranges from 900 kg ha^{-1} to 1700 kg ha^{-1} under different treatments plots. The result showed that highest grain yield was (1700 kg ha^{-1}) obtained under T_{11} : RDP + nutrient mobilizer (LNm43a). It was at par to T_{11} : 50 % RDP +12.5 kg $ZnSO_4$ + Biophos + Biozinc (1547 kg ha^{-1}), T_9 : 50 % RDP + Biophos + Biozinc (1533 kg ha^{-1}), T_{2} : RDP application (50 kg ha^{-1}) (1527 kg ha^{-1}) and T_7 : 50 % RDP and Biophos (1490 kg ha^{-1}).While lowest grain yield was 900 kg ha^{-1} obtained under T_1 : control plot.

Singh *et al.,* (2012) found that application of single super phosphate and phosphate solubilizing bacteria recorded highest seed yield (1.70 tonnes ha^{-1}) in fieldpea. Singh *et al*., (2018) found that combined application of 40 kg ha^{-1} P_2O_5 through DAP along with PSB significantly increase the seed yield (651 kg ha^{-1}). Teli *et al*., (2015) also found that combined application of 100% RDF + PSB + Rhizobium recorded highest grain yield (37.59 kg ha^{-1}). Hussain *et al*., (2015) found that zinc solubilizing bacteria *i.e Bacillus sp* significantly increase the yield in maize by increasing the zinc availability in soil. This finding was also confirmed by Sable *et al.,* (2014) in groundnut.

4.3.5 Stover yield

The data was presented regarding stover yield in Table 4.11. The data revealed that there was significant variation in stover yield of field among different treatments due to phosphate and zinc solubilizing. Significantly, highest stover yield 3950 kg^{-1} ha under T_{11} : RDP + nutrient mobilizer (LNm43a). It was at par with T_{10} : 50 % RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (3748 kg ha^{-1}), T_9 : 50 % RDP + Biophos + Biozinc (3709 kg ha^{-1}), T_7 : 50 % RDP and Biophos (3630 kg ha^{-1}) and T_{2} : RDP application (50 kg ha^{-1}) (3710 kg ha^{-1}). While, minimum stover yield was 2700 kg ha^{-1} recorded under control plot.

Singh *et al.,* (2012) revealed that application of single super phosphate and phosphate solubilizing bacteria recorded significantly highest stover yield (2.74 tonnes ha^{-1}) in fieldpea. Bhat *et al.,* (2013) found that combined inoculation of rhizobium and PSB in field pea recorded maximum stover yield(15.85 q ha^{-1})

4.3.6. Harvest Index

The data on harvest index are presented in Table 4.11. The result revealed that harvest index value ranges from (25 % to 30 %) under different treatment. The result showed that significantly highest harvest index was (30%) obtained under T_{11} : RDP + nutrient mobilizer (LNm 43a). It was at par with T_9 : 50 % RDP + Biophos + Biozinc (29.24 %), T_{10} : 50 % RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (29.21 %). T_2 : RDP application (50 kg ha^{-1}) (29.15%), T_6 : Application of Biophos + Biozinc (29.10 %), T_7 : 50 % RDP and Biophos (28.54 %) and T_8 : 12.5 kg $ZnSO_4$+ Biozinc (27.70 %). While, minimum harvest index was recorded (20 %) under T_1 : control plot.

Table 4.11 Effect of phosphate and zinc solubilzing microbes on seed yield, stover yield and harvest index of fieldpea

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index(%)
Absolute Control (Without P)	900	2700	25.00
RDP application (@ 50 kg ha^{-1})	1527	3710	29.15
Soil application of 25 kg $ZnSO_4$ ha^{-1}	940	2978	24.00
Application of Biophos	1090	2957	27.00
Application of Biozinc	990	2834	26.00
Application of Biophos + Biozinc	1240	3008	29.10
50 % RDP + Biophos	1490	3630	28.54
12.5 kg $ZnSO_4$+ Biozinc	1140	2983	27.70
50 % RDP + Biophos + Biozinc	1533	3709	29.24
50 % RDP+ 12.5 kg $ZnSO_4$+Biophos + Biozinc	1547	3748	29.21
RDP + nutrient mobilizer (LNm 43a)	1700	3950	30.00
SEm±	72	112	0.90
CD at 5%	213	333	2.70

4.4.1 Nutrient status of soil

The data regarding nutrient status of soil are presented in Table 4.12 and Table 4.13. Soil nutrient analysis was done at time of sowing and at harvest of crop. The result revealed that there was non- significant variation was found regarding nutrient status of nitrogen and potassium in soil after the harvest of crop among different treatments. But found that significant increase in phosphorus content in soil. Significantly, maximum phosphorus content in soil was 12.40 kg ha^{-1} determined under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. It as at par to T_4 : Appilcation of Biophos (11.89 kg ha^{-1}), T_2 : RDP application (@ 50 kg ha^{-1} (11.80 kg ha^{-1}) and T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (11.38 kg ha^{-1}).While, minimum phosphorus concentration was 251.23 observed under T_1 : control plot .

The data in Table 10.11 revealed maximum concentration of zinc was 1.13 mg kg^{-1} recorded under T_3 : Soil application of 25 kg $ZnSO_4$ ha^{-1}. It was at par to T_8 : 12.5 kg $ZnSO_4$ + Biozinc (1.07 mg kg^{-1}), T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (0.97 mg kg^{-1}), T_5 : Application of Biozinc (0.97 mg kg^{-1}), T_{11} : RDP + nutrient mobilizer (LNm 43a) (0.90 mg kg^{-1}), T_6 : Application of Biozinc + Biozinc (0.85 mg kg^{-1}) and T_7 : 50 % RDP, T_9 : 12.5 kg $ZnSO_4$ + Biozinc (0.80 mg kg^{-1}). While minimum concentration of zinc was 0.70 mg kg^{-1} recorded under control plot. The nutrient status of soil after harvest of crop regarding phosphorus and zinc was found to be significant due to phosphate and zinc solubilzing microbes.

Bhat *et al.,* (2013) found that combined inoculation of rhizobium and PSB in field pea significantly increase concentration of nutrients in soil after harvesting of crop (P : 19.64 kg ha^{-1}). Nyoki *et al.,* (2014) reported that inoculation of biofertilizer *Bradyrhizobium japonicum* in cowpea improve micronutrients content in soil especially zinc, iron, manganese and copper.

4.4.2 Nutrient content

The data regarding nutrient content are presented in Table 4.14. The result revealed that there was non- significant variation was found regarding nitrogen content in grain and straw among different treatments. But found that significant increase in phosphorus and potassium content in grain and stover. Significantly, maximum phosphorus content in grain and stover was 0.29 and 0.15 % determined under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. It was at par to T_2 : RDP application (@ 50 kg ha^{-1} (0.28 in grain and 0.15 stover), T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (0.27 in grain and 0.15 in stover), T_9 : 50 % RDP +12.5 kg $ZnSO_4$ +Biophos + Biozinc (0.15 in stover), T_4 : Application of

Biophos (0.14 in stover), T_5 : Application of Biozinc (0.14 in stover) and T_7 : 50 % RDP + Biophos (0.14 in stover). While, minimum phosphorus content was 0.21 and 0.12 observed under T_1 : control plot.

Significantly maximum potassium content in grain and stover was 1.38 and 3.62 % determined under T_{11} : RDP + nutrient mobilizer (LNm 43a) over rest of the treatments. It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (1.37 in grain and 3.59 in stover), T_9 : 50 % RDP +12.5 kg $ZnSO_4$ +Biophos + Biozinc (1.34 in grain and 3.54 in stover), T_5 : Application of Biozinc (3.45 in stover), T_6 : Application of Biophos + Biozinc (1.33 in grain and 3.45 in stover), T_2 : RDP application (@ 50 kg ha^{-1} (1.33 in grain and 3.39 in strover), T_7 : 50 % RDP + Biophos (1.30 in grain and 3.43 in stover), T_8 : 12.5 kg $ZnSO_4$+ Biozinc (3.43 in stover), T_3 : Soil application of 25 kg $ZnSO_4$ ha^{-1} (3.32 in stover), T_4 : Application of Biophos (1.27 in grain and 3.37 in stover), T_5 : Application of Biozinc (3.45 in stover) and T_8 : 12.5 kg $ZnSO_4$+ Biozinc (3.43 in stover), While, minimum potassium content in grain and stover was 1.17 and 3.27 observed under T_1 : control plot.

Table 4.12 Effect of phosphate and zinc solubilizing microbes on available nutrients status of soil after harvest of crop

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Absolute Control (Without P)	183.50	10.20	251.23
RDP application (@ 50 kg ha^{-1})	188.33	11.80	262.40
Soil application of 25 kg $ZnSO_4$ ha^{-1}	184.70	10.27	252.50
Application of Biophos	186.70	11.89	253.80
Application of Biozinc	187.60	10.28	257.20
Application of Biophos + Biozinc	188.00	11.10	257.60
50 % RDP + Biophos	188.17	11.19	260.60
12.5 kg $ZnSO_4$ + Biozinc	187.47	10.73	256.90
50 % RDP + Biophos + Biozinc	188.57	11.22	265.80
50 % RDP+12.5 kg $ZnSO_4$ +Biophos + Biozinc	189.13	11.38	266.00
RDP + nutrient mobilizer (LNm 43a)	190.43	12.40	275.20
SEm±	6.43	0.37	8.89
CD at 5%	NS	1.13	NS

Table 4.13 Effect of phosphate and zinc solubilizing microbes on nutrient status of zinc (mg kg^{-1}) in soil after the harvest of crop

Treatment	Zinc content (mg kg^{-1})
Absolute Control (Without P)	0.70
RDP application (@ 50 kg ha^{-1})	0.74
Soil application of 25 kg $ZnSO_4$ ha^{-1}	1.13
Application of Biophos	0.77
Application of Biozinc	0.97
Application of Biophos + Biozinc	0.85
50 % RDP + Biophos	0.80
12.5 kg $ZnSO_4$+ Biozinc	1.07
50 % RDP + Biophos + Biozinc	0.80
50 % RDP +12.5 kg $ZnSO_4$ +Biophos + Biozinc	1.97
RDP + nutrient mobilizer (LNm 43a)	1.90
SEm±	0.04
CD at 5%	0.11

Table 4.14 Effect of phosphate and zinc solubilizing microbes on nutrient content (kg ha^{-1}) in fieldpea

Treatments	N grain	N stover	P grain	P stover	K grain	K stover
Absolute Control (Without P)	3.81	1.27	0.21	0.12	1.167	3.21
RDP application (@ 50 kg ha^{-1})	3.99	1.37	0.28	0.15	1.325	3.39
Soil application of 25 kg $ZnSO_4$ ha	4.07	1.30	0.21	0.13	1.243	3.32
Application of Biophos	3.99	1.30	0.22	0.13	1.270	3.37
Application of Biozinc	4.36	1.36	0.21	0.14	1.332	3.45
Application of Biophos + Biozinc	4.36	1.35	0.22	0.14	1.299	3.44
50 % RDP + Biophos	4.02	1.33	0.24	0.14	1.269	3.43
12.5 kg $ZnSO_4$+ Biozinc	4.20	1.40	0.23	0.14	1.229	3.41
50 % RDP + Biophos + Biozinc	4.06	1.43	0.25	0.15	1.339	3.54
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	4.09	1.45	0.27	0.15	1.365	3.59
RDP + nutrient mobilizer (LNm 43a)	4.28	1.50	0.29	0.15	1.380	3.62
SEm±	0.140	0.04	0.00	0.00	0.044	0.19
CD at 5%	NS	NS	0.02	0.014	0.131	0.34

4.4.3 Nutrient uptake

The data regarding nutrient uptake of fieldpea are presented in Table 4.15,4.16,4.17,4.18. The data show that due to the inoculation of phosphate and zinc solubilizing microbes significantly improve the nutrient uptake of fieldpea among different treatments. Nitrogen, phosphorus and potassium are taken large quantities in early stage of crop growth. Legume require nitrogen until root nodules are formed. Potassium is taken gradually throughout the growth and development of the crop. The result also show that significantly highest nitrogen uptake value was 72.70 kg ha^{-1} in seed and 59.31 kg ha^{-1} in stover under T_{11} : RDP + nutrient mobilizer (LNm 43a). It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (63.57 kg ha^{-1} in seed and 54.65 kg ha^{-1} in stover), T_9 : 50% RDP + Biophos + Biozinc (62.57 kg ha^{-1} in seed and 52.99 kg ha^{-1}) and T_2 : RDP application (@ 50 kg ha^{-1}) (50.66 kg ha^{-1} in stover). While lowest nitrogen uptake was 34.32 kg ha^{-1} in seed and 32.32 kg ha^{-1} in stover recorded under T_1 : control plot.

The result also show that significantly highest phosphorus uptake value was 4.92 kg ha^{-1} in seed and 6.01 kg ha^{-1} in stover under T_{11} : RDP + nutrient mobilizer (LNm 43a). But it was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (6.01 kg ha^{-1} in stover), T_9 : 50% RDP + Biophos + Biozinc (5.43 kg ha^{-1} in stover) and T_7 : 50 % RDP + Biophos (5.09 kg ha^{-1} in stover). While lowest phosphorus uptake was 10.52 kg ha^{-1} in seed and 86.73 kg ha^{-1} in stover recorded under T_1 : control plot.

The result also show that significantly highest potassium uptake value was 23.49 kg ha^{-1} in seed and 143.14 kg ha^{-1} in stover under T_{11} : RDP + nutrient mobilizer (LNm 43a) . But it was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (21.21 kg ha^{-1} in seed and 134.94 kg ha^{-1} in stover), T_9 : 50% RDP + Biophos + Biozinc (20.59 kg ha^{-1} in seed and 131.69 kg ha^{-1} in stover), T_2 : RDP application (@ 50 kg ha^{-1}) (20.25 kg ha^{-1} in seed and 125.72 kg ha^{-1} in stover) and T_7 : 50 % RDP + Biophos (124 kg ha^{-1} in stover). While lowest potassium uptake was 10.52 kg ha^{-1} in seed and 86.73 kg ha^{-1} in stover recorded under T_1 : control plot.

The result show that zinc uptake in seed and stover almost remain same and found to be non- significant among the treatments. The data also revealed that there was significant variation on nutrient uptake (NPK) of fieldpea among different treatments due to presence of phosphate and zinc solubilizing microbes.

Singh *et al.,* (2012) found that application of single super phosphate and phosphate solubilizing bacteria recorded highest total nutrient uptake (N : 70.4 kg ha^{-1} and P : 16.2 kg ha^{-1}) in fieldpea. Bhat *et al.,* (2013) found that combined inoculation of rhizobium and PSB in field pea recorded highest total nutrient uptake (N : 78.17 kg ha^{-1}, P : 14.11 kg ha^{-1} and K : 41.87 kg ha^{-1}). Saritarani *et al.,* (2016) reported that inoculation of Rhizobium + PSB + PGPR + RDF in fieldpea enhance the nutrients uptake of Zn and K in fieldpea. Teli *et al*., (2015) reported that combination of 100% RDF + PSB + Rhizobium inoculation were found effective significantly increased total nutrient uptake (191.37 kg ha^{-1}) and phosphorus uptake by grain (17.79 kg ha^{-1}).

Table 4.15 Effect of phosphate and zinc solubilizing microbes on nitrogen uptake (kg ha^{-1}) in fieldpea

Treatment	Nitrogen uptake (kg ha^{-1})	
	Seed	Stover
Absolute Control (Without P)	34.32	32.32
RDP application (@ 50 kg ha^{-1})	60.95	50.66
Soil application of 25 kg $ZnSO_4$ ha	38.36	38.69
Application of Biophos	42.89	38.78
Application of Biozinc	43.15	38.48
Application of Biophos + Biozinc	54.07	40.44
50 % RDP + Biophos	60.13	48.32
12.5 kg $ZnSO_4$ + Biozinc	47.93	41.80
50 % RDP + Biophos + Biozinc	62.57	52.99
50 % RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc	63.57	54.65
RDP + nutrient mobilizer (LNm 43a)	72.70	59.31
SEm±	3.66	3.16
CD at 5%	10.81	9.32

Table 4.16 Effect of phosphate and zinc solubilizing microbes on phosphorus uptake (kg ha^{-1}) in fieldpea

Treatment	Phosphorus uptake (kg ha^{-1}) Seed	Stover
Absolute Control (Without P)	1.85	3.30
RDP application (@ 50 kg ha^{-1})	3.45	4.64
Soil application of 25 kg $ZnSO_4$ ha^{-1}	1.93	3.82
Application of Biophos	2.40	3.89
Application of Biozinc	2.07	3.80
Application of Biophos + Biozinc	2.72	4.13
50 % RDP + Biophos	3.57	5.09
12.5 kg $ZnSO_4$ + Biozinc	2.58	4.28
50 % RDP + Biophos + Biozinc	3.80	5.43
50 % RDP+12.5 kg $ZnSO_4$ +Biophos + Biozinc	4.16	5.61
RDP + nutrient mobilizer (LNm 43a)	4.92	6.01
SEm±	0.22	0.32
CD at 5%	0.64	0.94

Table 4.17 Effect of phosphate and zinc solubilizing microbes on potassium uptake (kg ha^{-1}) in fieldpea

Treatment	Potassium uptake (kg ha^{-1}) Seed	Stover
Absolute Control (Without P)	10.52	86.73
RDP application (@ 50 kg ha^{-1})	20.25	125.72
Soil application of 25 kg $ZnSO_4$ ha^{-1}	11.71	99.20
Application of Biophos	13.90	100.08
Application of Biozinc	13.19	97.89
Application of Biophos + Biozinc	16.12	103.56
50 % RDP + Biophos	18.94	124.68
12.5 kg $ZnSO_4$+ Biozinc	14.04	101.93
50 % RDP + Biophos + Biozinc	20.59	131.69
50 % RDP +12.5 kg $ZnSO_4$ + Biophos + Biozinc	21.21	134.94
RDP + nutrient mobilizer (LNm 43a)	23.49	143.14
SE±(m)	1.18	7.91
CD at 5%	3.47	23.24

Table 4.18 Effect of phosphate and zinc solubilizing microbes on zinc uptake ($mg\ kg^{-1}$) in fieldpea

Treatment	Zinc uptake ($mg\ kg^{-1}$) Seed	Stover
Absolute Control (Without P)	17.58	22.20
RDP application (@ 50 kg ha^{-1})	17.68	22.67
Soil application of 25 kg $ZnSO_4$ ha^{-1}	19.80	25.60
Application of Biophos	17.81	22.80
Application of Biozinc	18.60	23.60
Application of Biophos + Biozinc	17.98	23.07
50 % RDP + Biophos	17.88	22.70
12.5 kg ZnSO4+ Biozinc	19.27	25.80
50 % RDP + Biophos + Biozinc	18.35	25.20
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	18.05	23.33
RDP + nutrient mobilizer (LNm 43a)	18.18	23.90
SEm±	0.63	2.42
CD at 5%	NS	NS

4.4.4 Protein content and protein yield

The data regarding protein content and protein yield are presented in Table 4.19. The result revealed that there was non- significant variation regarding protein content in grain of fieldpea due to phosphate and zinc solubilizing microbes. The result also show significantly higher protein yield of fieldpea among different treatments. The result show that higher protein yield (417 kg ha^{-1}) was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a). But it was at par to T_{10} : 50 % RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (375 kg ha^{-1}), T_9 : 50 % RDP + Biophos + Biozinc (365.1 kg ha^{-1}) and T_2 : RDP application @ 50 kg ha^{-1} (363.9 kg ha^{-1}). While lowest protein yield was 200.2 kg ha^{-1} recorded under T_1 : control plot.

Singh *et al.*, (2009) found that application of single super phosphate and phosphate solubilizing bacteria recorded significantly highest protein yield (393.6 kg ha^{-1}) in fieldpea. Bhat *et al.*, (2013) recorded highest protein yield under Rhizobium and PSB inoculated treatment.

Table 4.19 Effect of phosphate and zinc solubilizing microbes on protein content (%) and protein yield (kg ha^{-1}) of fieldpea

Treatment	Protein content (%)	Protein yield (kg ha^{-1})
Absolute Control (Without P)	22.20	200.2
RDP application (@ 50 kg ha^{-1})	23.80	363.9
Soil application of 25 kg $ZnSO_4$ ha^{-1}	22.30	210.2
Application of Biophos	22.40	245.3
Application of Biozinc	22.23	220.2
Application of Biophos + Biozinc	22.43	278.5
50 % RDP + Biophos	22.83	340.8
12.5 kg $ZnSO_4$+ Biozinc	22.63	258.7
50 % RDP + Biophos + Biozinc	23.73	365.1
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	24.13	375.0
RDP + nutrient mobilizer (LNm 43a)	24.5	417.0
SEm±	0.86	21.8
CD at 5%	NS	64.4

5. Economics

The data present in Table 4.20 regarding economic of fieldpea. Several economic indices are available to evaluate the profitability of particular treatments like cost of cultivation, gross realization, net realization and benefit cost ratio. The cost of cultivation varies according to different treatments. It includes value of seed, manures, fertilizers, pesticides, herbicides and labour etc. Due to inoculation of phosphate and zinc solubilzing microbes maximum gross realization value (Rs 80450 ha^{-1}), net realization value (Rs 58234 ha^{-1}) and benefit cost ratio (3.62) was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a). While, lowest gross realization value (Rs 43200 ha^{-1}), net realization value (Rs 22400 ha^{-1}) and benefit cost ratio (2.08) recorded under T_1 : control plot due to low level of nutrients which was directly responsible for the growth and yield attributes of fieldpea. RDP + nutrient mobilizer (LNm 43a) show perfect combination of inorganic nutrient and organic nutrient for achieving higher gross realization, net realization value and benefit cost ratio, found superior among all the treatment.

Mishra *et al.*, (2010) recorded maximum gross income (Rs 33913 ha^{-1}) and net profit (Rs 26187 ha^{-1}) by inoculation of Rhizobium + PSB + PGPR along 100%

RDF in fieldpea. Mishra *et al.,* (2014) recorded highest net return in snow pea (*Pisum sativam var. microcarpan L.*) at 100% recommended dose of chemical fertilizers combined with vermicompost and biofertilizers in presence of lime. Hyder *et al.,* (2016) confirmed that application of Biozote + Vermizote 1tn ha^{-1} + 75% of RDF recorded recorded maximum pea yield (3.9 t ha^{-1}) due to significant increase in nutrient and protein content of pea

Table 4.20. Effect of phosphate and zinc solubilizing microbes on economics (gross realization, net realization value and benefit cost ratio) of fieldpea

Treatments	Cost of cultivation (Rs ha^{-1})	Gross realization (Rs ha^{-1})	Net realization (Rs ha^{-1})	B :C ratio
Absolute Control (Without P)	20800	43200	22400	2.08
RDP application (@ 50 kg ha^{-1})	21458	74425	52967	3.47
Soil application of 25 kg $ZnSO_4$ ha^{-1}	21675	45278	23603	2.09
Application of Biophos	20900	52007	31107	2.49
Application of Biozinc	20900	47384	26484	2.27
Application of Biophos + Biozinc	21000	58808	37808	2.80
50 % RDP + Biophos	21558	70680	49122	3.28
12.5 kg $ZnSO_4$ + Biozinc	21338	54283	32945	2.54
50 % RDP + Biophos + Biozinc	21658	72694	51036	3.36
50 % RDP + 12.5 kg $ZnSO_4$+ Biophos + Biozinc	22096	73363	51267	3.32
RDP + nutrient mobilizer (LNm 43a)	22216	80450	58234	3.62

Fig.1 Germination

Fig. 2 Establishment of crop

Fig.3 Measurement of plant height of fieldpea

Fig.4 Flowering in fieldpea

Fig.5 Pod formation and development

Fig.6   At the time of harvesting

CHAPTER- V
SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH WORK

The research work was proposed to evaluate **"Effect of phosphate and zinc solubilizing microbes on profitability and productivity of fieldpea"** was conducted at Instructional Cum Research Farm, IGKV, Raipur during *rabi* season of 2019-20. Main objective was to study the effect of phosphate and zinc solubilizing microbes on growth and yield attributes of fieldpea and also found out the best treatment which are economically fessible to the farmers.

The experimental design was Randomized Block Design and having three replication. The experiment consist of 11 treatments. Experiment crop was fieldpea and variety was Indira matar-1 having good branching ability and yield potential. 80 kg ha^{-1} seed was sowned manually with a spacing of 30 cm X 10 cm row to row and plant to plant in the depth of 4-5 cm in soil for proper nitrogen fixation. Sowing was done on 11-11-2019. Recommended dose of nitrogen, potassium and sulphur @ 20 kg ha^{-1} respectively, applied as basal dose and seed was treated with 5 g rhizobium culture kg^{-1} seed at the time of sowing common to all treatments. But 50% recommended dose of phosphorus was applied to some treatment (T_7,T_9 and T_{10}) and RDP to another treatments (T_2 and T_{11}) to observe and compare the effectiveness of P to the other treatment (without P). For the comparision, Biophos and Biozinc was also applied @ 5ml kg^{-1} seed in treatment (T_4, T_5, T_6,T_7,T_8,T_9 and T_{10}) and combined application of RDP and (LNm 43a) nutrient mobilizer in T_{11}.

The research work consist of numbers of observation taken from each plot at different time interval of crop growth of fieldpea. Observed plants were tagged properly for further observation. Observation was recorded at 30, 60, 90 DAS and at harvest of crop. The following observation were taken on growth and yield attributes of fieldpea are plant population (m^{-2}), plant height (cm), number of branches plant^{-1}, number of leaves plant^{-1}, number of nodules plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, 100 seed weight (seed index), stover yield (kg ha^{-1}), seed yield (kg ha^{-1}). To determine the physical-chemical properties of experimental soil, several analysis was done to determine the nitrogen, phophorus, potassium and zinc content in the soil at before sowing and after harvesting of crop. Nutrient uptake was also calculated by estimating the nutrient concentration in seed and stover (kg ha^{-1}). Protein content was calculated by using the percentage of nitrogen and using 6.25 factor.

To evaluate the best treatment for fieldpea, economics evaluation was done. Several economic indices are available to evaluate the profitability of plots *viz.* cost of cultivation, gross realization, net realization and benefit cost ratio. Since, price of farm product changes from year to year and place to place, the profitability of treatment plot was also changes accordingly.

The salient findings of present investigation are summaried below

1. Plant population show no significant differences among the treatments at 30 DAS and at final. Therefore, all the treatments show non- significant impact on plant population (m^{-2}) of fieldpea. Plant population remain unaffected at initial and final due to the presence of phosphate and zinc solubilizing microbes.
2. Significant impact of microbes on plant height of fieldpea. Taller plant height was recorded under T_{11} : RDP + nutrient mobilizers (LNm 43a). It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50% RDP + Biophos + Biozinc, T_2 : RDP application (@ 50 kg ha^{-1}) (at 60 DAS) and T_7 : 50% RDP + Biophos (at 30 DAS). While, shorter plant height was observed under T_1 : control plot due to absence of RDP and bio-inoculant.
3. Due to inoculation of nutrient solubilizing microbes and RDP, plant promoting more numbers of branches. Maximum numbers of branches $plant^{1}$ under the T_{11} : RDP + nutrient mobilizers (LNm 43a). It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc and T_9 : 50% RDP + Biophos + Biozinc. The minimum number of branches $plan^{t-1}$ was recorded under T_1 : control plot.
4. Significantly, maximum number of leaves $plant^{-1}$ was produced under the T_{11} : RDP and nutrient mobilizer. It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50% RDP + Biophos + Biozinc, T_2 : RDP application (@ 50 kg ha^{-1}, T_7 : 50 % RDP + Biophos and T_6 : Application of Biophos + Biozinc. Minimum number of leaves $plant^{-1}$ was produced under T_1 : control plot.

5. Among the treatments, numbers of nodules plant^{-1} almost remain the same due to phosphate and zinc solubilizing microbes in fieldpea. Therefore, the data on numbers of nodules plant^{-1} revealed that there was non - significant variation in numbers of nodules at 30 DAS and 60 DAS.
6. Significantly, maximum leaf area plant^{-1} was recorded under T_{11} : RDP + nutrient mobilizer (LNm43a) It was at par to T_{10} : 50% RDP + 12.5 kg ZnS_{O4} + Biophos + Biozinc, T_9 : 50% RDP + Biophos + Biozinc, T_2 : RDP application (@ 50 kg h^{a-1}) (at 90 DAS) and T_7 : 50 % RDP + Biophos. While, minimum leaf area plant^{-1} was observed under T_1 : control plot.
7. Significantly, maximum leaf area index was recorded at 60 and 90 DAS under T_1 : RDP + nutrient mobilizer (LNm43a). It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc and T_9 : 50% RDP + Biophos + Biozinc. While, minimum leaf area index was at 60 and 90 DAS observed under T_1 : control plot.
8. Among the treatment, maximum leaf area duration was observed at 60 DAS found under T $_{11}$: RDP + nutrient mobilizer (LNm43a). It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc and T_9 : 50% RDP + Biophos + Biozinc .While, minimum leaf area duration was recorded under T_1 : control plot.
9. Significantly, maximum dry matter accumulation plant^{-1} at 30, 60, 90 DAS and harvest was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50% RDP + Biophos + Biozinc, T_7 : 50 % RDP + Biophosmand T_2 : RDP application (@ 50 kg ha^{-1}). While, minimum dry matter accumulation plant^{-1} was recorded under T_1 : control plot
10. Significantly, increase in crop growth rate and relative growth rate at 30 DAS and at 90 DAS under T_{11} : RDP + nutrient mobilizer (LNm43a) due to phosphate and zinc solubilizing microbes. Minimum crop growth rate and relative growth rate under T_1 : control plot.
11. Significantly, maximum number of pods was recorded under T_{11} : RDP and nutrient mobilizers (LNm 43a). While, the minimum number of pods plant^{-1} was recorded under T_1 : control plot.

12. Due to phosphate and zinc solubilzing microbes, the result was found to be non- significant on numbers of seeds pod^{-1} of fieldpea.
13. Among different treatments, there was no significant impact was observed with regard to seed index. Therefore, seed index value remain same, neither heavier nor lighter seed index among the treatments due to phosphate and zinc solubilzing microbes
14. Significantly, higher grain yield was obtained under T_{11} : RDP + nutrient mobilizers (LNm 43a). It was at to T_{10} : 50 % RDP +12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50 % RDP + Biophos + Biozinc, T_2 : RDP application (@ 50 kg ha^{-1}) and T_7 : 50 % RDP and Biophos. While lowest grain yield was obtained under T_1 : control plot.
15. Significantly, maximum stover yield was recorded under T_{11} : RDP + seed treatment with nutrient mobilizers (LNm 43a). It was at to T_{10} : 50 % RDP +12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50 % RDP + Biophos + Biozinc, T_2 : RDP application (@ 50 kg ha^{-1}) and T_7 : 50 % RDP and Biophos. While, minimum stover yield was recorded under T_1 : control plot.
16. Significantly, highest harvest index was obtained under T_{11} : RDP + nutrient mobilizer (LNm43a). It was at par to T_9 : 50 % RDP + Biophos + Biozinc , T_{10} : 50 % RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_2 : RDP application (50 kg ha^{-1}), T_6 : Application of Biophos + Biozinc (29.10 %), T_7 : 50 % RDP and Biophos and T_8 : 12.5 kg $ZnSO_4$+ Biozinc. While, minimum harvest index was recorded under T_1 : control plot.
17. Due to phosphate and zinc solubilizing microbes in fieldpea, maximum phosphorus content in soil was determined under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. It was at par to T_4 : Appilcation of Biophos, T_2 : RDP application (@ 50 kg ha^{-1}) and T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc. While, minimum phosphorus concentration was observed under T_1 : control plot .
18. Due to phosphate and zinc solubilizing microbes in fieldpea, maximum concentration of zinc in soil was recorded under T_3 : Soil application of 25 kg $ZnSO_4$ ha^{-1}. It was at par to T_8 : 12.5 kg $ZnSO_4$ + Biozinc, T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_5 : Application of Biozinc, T_{11} :

RDP + nutrient mobilizer (LNm 43a), T_6 : Application of Biozinc + Biozinc and T_7 : 50 % RDP, T_9 : 12.5 kg $ZnSO_4$ + Biozinc. While minimum concentration of zinc was recorded under control plot.

19. Maximum phosphorus content in grain and stover was determined under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. It was at par to T_2 : RDP application (@ 50 kg ha^{-1} , T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50 % RDP +12.5 kg $ZnSO_4$ +Biophos + Biozinc, T_4 : Application of Biophos, T_5 : Application of Biozinc and T_7 : 50 % RDP + Biophos. While, minimum phosphorus content in grain and stover was observed under T_1 : control plot.
20. Maximum potassium content in grain and stover was determined under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc , T_9 : 50 % RDP +12.5 kg $ZnSO_4$ +Biophos + Biozinc, T_5 : Application of Biozinc, T_6 : Application of Biophos + Biozinc, T_2 : RDP application (@ 50 kg ha^{-1}, T_7 : 50 % RDP + Biophos, T_8 : 12.5 kg $ZnSO_4$+ Biozinc, T_3 : Soil application of 25 kg $ZnSO_4$ ha^{-1}, T_4 : Application of Biophos, T_5 : Application of Biozinc and T_8 : 12.5 kg $ZnSO_4$+ Biozinc. While, minimum potassium content in grain and stover was observed under T_1 : control plot.
21. Significantly, highest nitrogen uptake was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a) among the treatments. It was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50% RDP + Biophos + Biozinc and T_2 : RDP application (@ 50 kg ha^{-1}). While lowest nitrogen uptake was recorded under T_1 : control plot.
22. Due to phosphate and zinc solubilzing microbes, highest phosphorus uptake value was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a). But it was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50% RDP + Biophos + Biozinc and T_7 : 50 % RDP + Biophos. While lowest phosphorus uptake was recorded under T_1 : control plot.
23. Significantly, highest potassium uptake in grain and stover was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a) . But it was at par to T_{10} : 50% RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc, T_9 : 50% RDP + Biophos

+ Biozinc , T_2 : RDP application (@ 50 kg ha^{-1}) and T_7 : 50 % RDP + Biophos. While lowest potassium uptake in grain and stover was recorded under T_1 : control plot.

24. Among different treatments, zinc uptake in seed and stover almost remain same and found to be non- significant due to phosphate and zinc solubilzing microbes
25. Significantly, higher protein yield was recorded under T_{11} : RDP + nutrient mobilizer (LNm 43a). It was at par to T_{10} : 50 % RDP + 12.5 kg $ZnSO_4$ + Biophos + Biozinc (375 kg ha^{-1}), T_9 : 50 % RDP + Biophos + Biozinc (365.1 kg ha^{-1}) and T_2 : RDP application (@ 50 kg ha^{-1}). While lowest protein yield was recorded under T_1 : control plot.

23 Among the different treatments, maximum gross realization, net realization and benefit cost ratio was obtained under T_{11} : RDP and nutrient mobilizers (LNm 43 a) due to the inoculation of phosphate and zinc solubilizing microbes.

CONCLUSION

On the basis of the experimental result, following conclusion can be drawn:

1. It may concluded that combined application of RDP + nutrient mobilizers (LNm 43a) were found effective and significantly improved overall growth attributes and yield attributes of fieldpea in terms of plant height , number of branches plant^{-1}, number of leaves plant^{-1}, number of pods plant^{-1}, grain yield and stover yields as compared to other treatments.
2. Significantly, highest phosphorus content in soil , NPK content in seed and stover and also highest protein yield was recorded under RDP + nutrient mobilizers (LNm 43a**).**
3. Inoculation of phosphate and zinc solubilizing microbes in fieldpea have beneficial effect on achieving a highest gross realization, net realization and benefit cost ratio under T_{11} : RDP and nutrient mobilizers (LNm 43 a). Due to better performance of yield attributes, yield increases and result in higher

economic returns considered as cost effective combination of organic and inorganic nutrient sources.

Suggestion for future research work :

With the knowledge and experience gained about experiment and finding result during the research work, the following consideration should be made for future research work :

1. The same experiment should be repeated for one or two years for final recommendations.
2. The experiment should be repeated to know variation of plant attributes in particular climate
3. Use of appropriate strains of microbes which have wide viability to sustain in different climates.

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APPENDIX – A

Weekly Meteorological Data (November, 2019 to March, 2020)

Wk No.	Date	Max. Temp. (°C)	Min. Temp. (°C)	Rain-fall (mm)	Rainy days	Relative Humidity (%)		Vapour Pressure (mm of Hg)		Wind Velocity (Kmph)	Evapo-ration (mm)	Sun Shine (hours)
						I	II	I	II			
	2019											
40	**Oct 01-07**	32.0	24.3	1.8	0	90	64	22.0	21.7	3.8	25.3	7.5
41	**08-14**	31.3	23.6	1.2	0	91	64	21.2	20.5	2.4	23.4	5.4
42	**15-21**	30.9	21.8	51.0	3	92	65	20.2	18.9	2.6	21.9	5.7
43	**22-28**	28.1	22.2	27.6	1	92	71	19.6	19.8	3.7	12.5	2.8
44	**29-04**	31.4	22.2	0.0	0	92	51	19.6	17.2	1.2	19.2	6.0
45	**Nov 05-11**	30.6	23.0	81.6	4	91	65	20.7	20.1	3.0	92.0	5.5
46	**12-18**	29.6	15.5	0.0	0	90	38	13.2	11.5	1.8	20.0	8.7
47	**19-25**	30.2	15.2	0.0	0	89	38	12.8	11.8	1.4	20.2	8.2
48	**26-02**	29.7	16.3	0.0	0	90	43	13.3	12.8	2.0	20.4	6.3
49	**Dec 03-09**	28.0	13.3	0.0	0	84	34	10.5	9.4	2.4	21.4	7.6
50	**10-16**	29.5	15.3	0.0	0	91	48	12.5	12.9	1.7	17.3	5.2
51	**17-23**	26.7	14.1	0.8	0	88	42	11.3	11.0	1.9	16.6	4.9
52	**24-31**	26.1	11.9	0.0	0	81	35	9.5	8.2	2.5	21.6	5.7
	2020											
1	**Jan 01-07**	23.3	12.9	19.4	1	84	55	10.3	10.5	4.1	15.2	3.5
2	**08-14**	25.1	10.8	3.2	1	90	46	9.7	9.8	2.1	16.4	6.2
3	**15-21**	28.6	14.1	0.0	0	88	48	11.3	12.8	1.8	17.3	5.7
4	**22-28**	28.8	13.4	0.0	0	87	39	10.7	11.1	1.8	19.7	7.3
5	**29-04**	26.1	13.9	0.0	0	76	46	10.6	10.1	2.9	21.6	4.3
6	**Feb 05-11**	21.3	13.6	49.6	2	94	66	11.9	11.6	4.1	11.9	2.4
7	**12-18**	29.7	11.9	0.0	0	88	27	10.1	8.5	2.2	26.2	9.8
8	**19-25**	31.4	15.5	35.8	1	87	45	12.8	13.3	2.7	24.9	6.6
9	**26-04**	30.0	16.3	0.2	0	87	39	13.5	12.5	1.9	25.4	7.8
10	**Mar 05-11**	30.1	19.4	1.8	0	87	52	16.1	15.5	3.7	25.5	6.7
11	**12-18**	31.2	20.8	37.2	2	89	54	17.8	17.9	3.0	24.6	6.5
12	**19-25**	33.6	20.0	1.6	0	84	37	16.5	14.0	3.0	31.1	8.3
13	**26-01**	35.1	21.9	8.4	1	78	36	17.5	14.7	3.4	34.4	7.3
		29.17	17.05	321.2	16						626	

Source:Department of Agricultural Meteorology, Indira Gandhi Agricultural University, Raipur (C.G)

APPENDIX – B

Appendix-B: Calculation of fixed cost of cultivation (Rs ha-1) of fieldpea

S.No.	Particulars	Inputs	Rate/Unit (Rs)	Total cost(Rs ha^{-1})
1	**Land preparation**			
	Ploughing	Tractor 2 hr	800/hr	1600
2	**Seed and sowing**			
	Seed	100 kg ha^{-1}	65/kg	6500
	Sowing	Seed drill	800/ha	800
	Rhizobium	1 pkt	25/pkt	25
	Labour cost	4 men day	190	760
3	**Fertilizer**			
	N	20	13/kg	260
	K_2O	20	28/kg	560
	S	20	44/kg	880
4	**Plant protection**			
	A chemical	Quinolphos	2.5 liter	725
	B labour	2 men day	190	380
5	**Weed management**			
	Hand weeding	14 men day	190	2660
6	**Harvesting**	12 men day	190	2280
	Threshing and winnowing	12 men day	190	2280
A	**Common cost**			
B	**Miscellaneous cost**	10% of common cost		1890
	Total cost (A+B)			20800

Note: Price of seed Rs. 65 kg^{-1}, selling price grain Rs. 45 kg^{-1}, Stover Rs. 1 kg^{-1}.

APPENDIX – C

Appendix- C : Variable cost (Rs ha-1) of fieldpea

Treatment	**Treatment cost**	**Total cost (Fixed + Treated)**
Absolute Control (Without P)		20800
RDP application (@ 50 kg/ha)	658	21458
Soil Appli. of 25 kg $ZnSO_4$/ha	875	21675
Application of Biophos	100	20900
Application of Biozinc	100	20900
Application of Biophos + Biozinc	200	21000
50 % RDP + Biophos	758	21558
12.5 kg $ZnSO_4$+ Biozinc	538	21338
50 % RDP + Biophos + Biozinc	858	21658
50 % RDP+12.5 kg $ZnSO_4$+Biophos + Biozinc	1296	22096
RDP + nutrient mobilizer (LNm 43a)	1416	22216

RESUME

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